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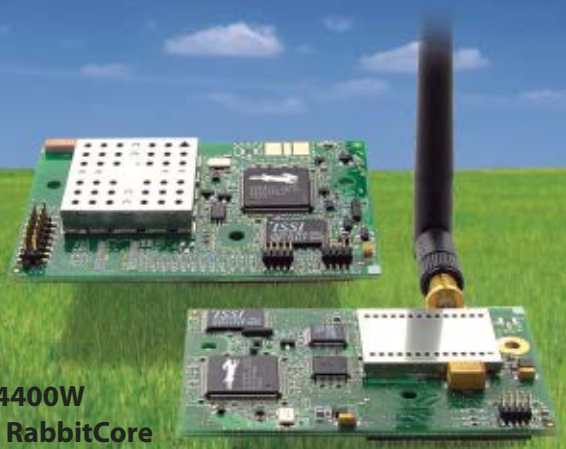

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NUTS AND VOLTS

AUGUST 2007

SPECIAL SECTION THIS ISSUE!

GREEN POWER!

With "going green" so prevalent in the news these days, we figured it's time to get our *Nuts* readers into the action.

Check out the special section on solar power that starts on Page 50. There's a couple projects, tips on saving money, and info on Hybrids, to name a few things. Be sure and let us know if you'd like to see regular coverage on this timely topic!

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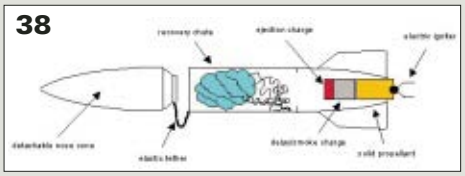

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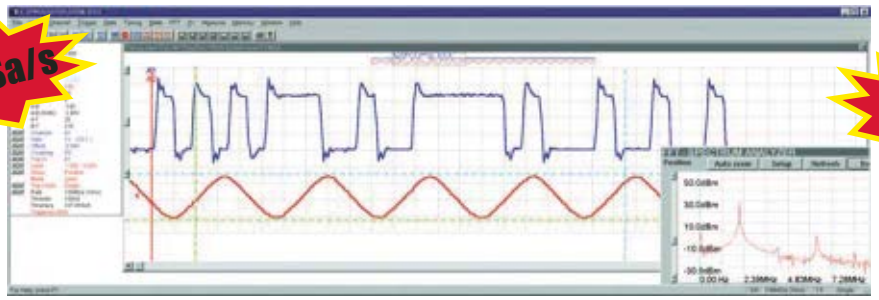

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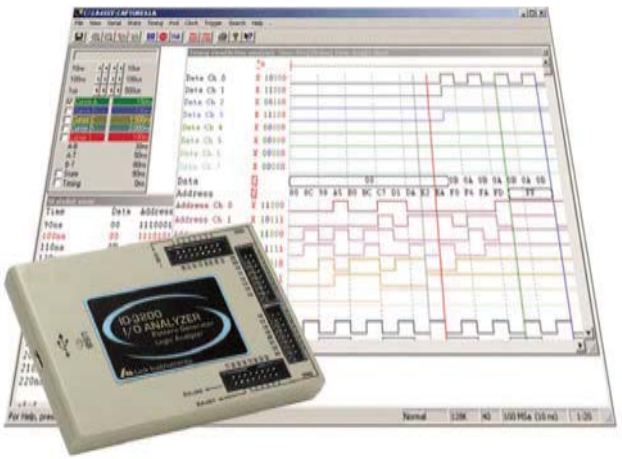

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

As highlighted by several articles in this issue, green innovation — using energy efficient alternatives to fossil fuel and other methods of minimizing the release of carbon in the environment — has bubbled to the surface of our social consciousness. Increased gasoline prices at the pump, US military involvement in the Middle East, and maneuvering of political parties in preparation for the upcoming presidential election, have reinvigorated the green energy product and service industry and created opportunities for innovators.

Our per capita consumption of foreign oil and carbon emissions can be minimized by forgoing driving in favor of bicycling or use of hybrid vehicles, turning off unnecessary lights, using stairs instead of escalators or elevators, and adjusting the thermostat to reduce energy consumed by heating and air conditioning systems. However, for most of us, such measures are unrealistic or at least unacceptable. Shopping mall operators aren't about to turn down the lights or reduce the air conditioning, and for many of us, conventional SUVs remain the safest, most affordable option for the daily commute, shopping, and transporting the kids.

Fortunately, and paradoxically, technology has a central role in going green. Consider the simple, painless step of replacing halogen and incandescent bulbs with more efficient fluorescent bulbs. More technically advanced options include replacing traditional home heating and cooling systems with geothermal units, installing solar panels for generating electricity and heating water, smart thermostats for more accurate cycling of heating and cooling, and motion-activated light switches to reduce power consumption.

Often, there are multiple incentives for thinking green. For example, not only does fluorescent lighting technology pay for itself through lower energy costs, but the up-front purchase price is often subsidized by local energy providers. See the Database of State Incentives for Renewables & Efficiency (DSIRE) for information on state, local, utility, and federal incentives that promote renewable energy and energy efficiency at **www.dsireusa.org**.

According to the database, California's Marin County offers a $500 rebate for a photovoltaic system, $300 for a solar hot water heater, and $200 for a solar pool heater. Of particular note is that innovation is also rewarded by the government. For example, as noted in DSIRE, the state of Massachusetts offers a personal income tax deduction for any income received from the sale of a patent or royalty income from a patent beneficial for energy conservation or alternative energy development.

Even if you can't afford a solar water heater and solar electric generator, and a wind turbine simply isn't feasible in your high-rise apartment or condo, you can make a significant difference in how you impact the environment with small behavior changes. Consider upgrading your lead-based soldering equipment so that you can work with lead-free solder. And make certain to contact your local hazardous waste disposal and collection service for information on how to safely dispose of your unused lead solder.

Furthermore, when you order parts and printed circuit boards for your next project, make certain that you buy the lead-free varieties that comply with the Restriction of Hazardous Substances (RoHS) Directive. RoHS components typically cost a few cents more than leaded components, but when you finally dispose of them, you won't be adding lead to the ground water.

Given the potential impact of electronic technology in reducing carbon emissions, I'd like to dedicate a full issue of *Nuts & Volts* to green innovation. But I need your help. If you've succeeded in building a more efficient solar-to-power grid converter, battery charger, or other electronic device or system that reduces energy consumption, I encourage you to share your innovations with our readers. **NV**

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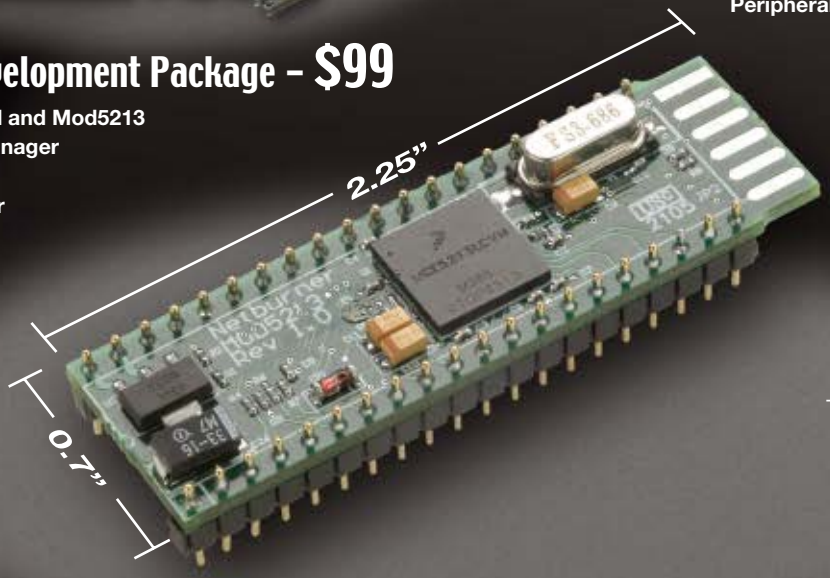

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READER FEEDBACK

GENERATED ERRORS

Gerard Fonte's interesting article describing how to generate analog signals from digital has a couple of errors.

The standard R-2R ladder shown in Figure 3 would (by definition) require one set of resistors of one value and a second set of exactly twice that value. R1,R2,R3,R4 should be twice R5,R6,R7,R8 or 2K in this example.

Under the description of Pulse to Frequency Conversion (page 82, Jul '07 issue) the example given has a math error. A 5V digital signal that is logic for 10% of the time would have an average voltage of 500 mV (5V * 10/100), not 1V as stated.

Peter Stonard,
Campbell, CA

Thank you for your interest and comments on the article. You are correct on both counts. The reason for the mistakes is simple: I just screwed up. Hopefully these errors weren't too confusing. — Gerard Fonte

CALLING ALL CLOCK CYCLES

In the serial port article in Jun '07, G.Y. Xu seems to forget about the four clock cycles it takes for the call to DLY49 µS. So, the call to DLY49 takes 54 µS.

Bob Fleming

PART DEPARTED

When I submitted my "Probing Cores" article, the ICL8038 — an old, obscure but quite popular part originally made by Intersil — was still available from Jameco. Since then, the manufacturer has stopped making it and Jameco is out of stock.

After a Google search, I've found that the Harris (was Intersil) ICL8038 is available from **futurlec.com**. JDR Microdevices **jdr.com** claim to have it, as well.

Tom Napier

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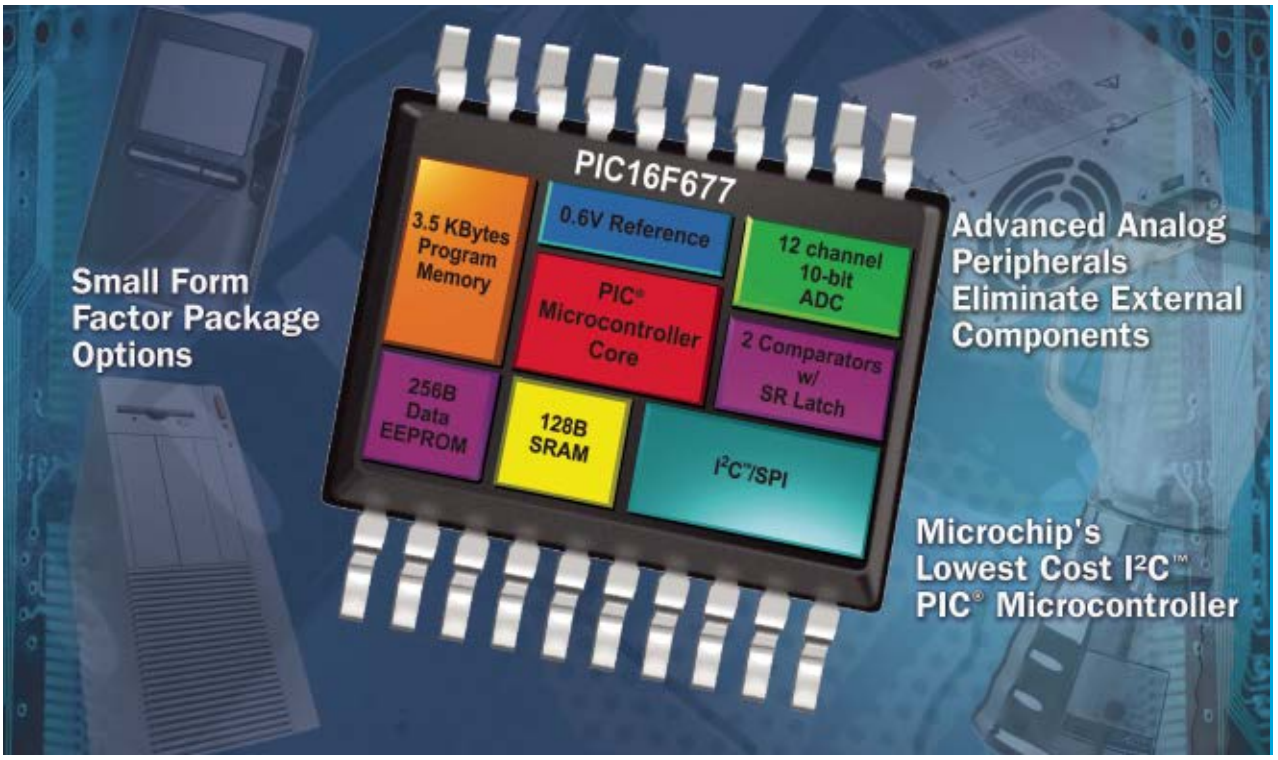

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	PIC16F689	4096	256	256	12	1/1	EUSART, SPI/I²C™	PDIP, SSOP, SOIC, 4mm x 4mm QFN
	PIC16F690	4096	256	256	12	2/1	ECCP+, EUSART, SPI/I²C™	PDIP, SSOP, SOIC, 4mm x 4mm QFN
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TECH KNOWLEDGEY 2007

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

WORKING UNDER PRESSURE

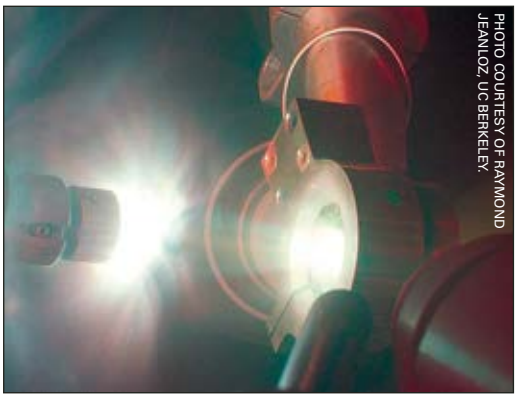

PHOTO COURTESY OF RAYMOND JEANLOZ, UC BERKELEY.

■ A laser vaporizes a diamond cell, inducing a shock wave and generating pressures >10 million atm.

The diamond anvil cell (DAC) has been around since 1958, when it was invented by Weir, Van Valkenburg, Lippincott, and Bunting at what was then called the National Bureau of Standards. The original version — consisting of a lever-arm mechanism and two opposing conical diamonds pressed together — came in handy for conducting infrared spectroscopic measurements on powders squeezed between the two halves of the anvil, but the amount of applied pressure was limited and difficult to calibrate.

Refinements increased achievable long-term pressures of four to five million atm, which is slightly higher than that existing at the center of the Earth. Even greater pressures can be generated by applying laser-induced shock waves, but only for a fraction of a second, and only at very high temperatures. But now, a variation on the theme promises scientists the ability to squeeze materials under pressures 100 to 1,000 times greater than previously possible.

Raymond Jeanloz, a professor at the University of California, Berkeley (**www.berkeley.edu**) and some colleagues have developed a technique that hits one of the diamonds with several laser beams, thereby vaporizing it and compressing the sample even more. The compression lasts only a nanosecond or two, but this is still enough time to study the properties of the sample.

According to Jeanloz, this is important because, at a million atmospheres, "materials go from being transparent insulators to becoming metallic or even superconducting. The periodic table is completely changed at high pressures. There is reason to expect that when we go from the million atmosphere range to the billion atmosphere range, again there will be huge changes in chemical bonding and material properties."

Jeanloz et al. have already achieved pressures near 10 million atm using a 30 kJ laser at the University of Rochester. They hope to eventually use Lawrence Livermore Labs' 2 MJ laser to surpass one billion atm.

IR TELESCOPE IN A DRUM

PHOTO BY GUY PLANTE, COURTESY OF LAVAL.

■ A 3.7-m diameter liquid mercury mirror at Laval University. There are no detectable mercury vapors in the air because a thin transparent layer of oxide covers the surface.

It's no secret that setting up a space-bourne telescope is an expensive and complex process, but a new concept from NASA's Ames Research Center (**www.nasa.gov/centers/ames/home/index.html**) could someday change that (relatively speaking). In a recent paper, Ermanno Borra, of Laval University (**www.ulaval.ca**), and coauthor S. Pete Worden, of NASA, described how having astronauts assemble a telescope on the surface of the moon could eliminate much of the cost of shipping, assembling, and maintaining a unit that employs a solid mirror, and also provide better performance.

They envision an optical-infrared telescope with a 66 to 328 ft (20 to 100 m) aperture, capable of observing objects 100 to 1,000 times fainter than the planned James Webb Space Telescope, which isn't actually scheduled for launch until 2013 (for a description, see **www.jwst.nasa.gov**). The liquid would be carried to the moon in a drum and emptied onto a rotating mesh that robotically unfolds like an umbrella, with surface tension keeping the liquid from leaking through the mesh. The lab prototype is a liquid made of ionic salts that remain fluid at low temperatures, atop of which is deposited a layer of chromium particles and then a layer of silver particles.

The result, if it comes to fruition, will be a telescope that can see back to the early phases of the universe, just following the "Big Bang." It would also be useful for studying normal and dwarf galaxies. Don't hold your breath waiting to see the images, though. The authors speculate that the first one will be built no sooner than 2020.

COMPUTERS AND NETWORKING

COMPUTERS OFFER OS ALTERNATIVE

■ Three Dell computers, including the XPS 410n shown, will now be offered with preinstalled Linux.

Apparently, Dell (**www.dell.com**) has received about 30,000 requests for machines that come with Linux instead of Windows, and the company has responded, unveiling three consumer systems — the XPS™ 410n and Dimension™ E520n desktops and the Inspiron™ E1505n notebook — with Ubuntu 7.04 Linux (**www.ubuntu.com**) factory installed.

Ubuntu is a community-developed OS that involves no software licensing costs (sorry, Bill), so the base price for the computers is reduced. The base price for the E1505n and E520n is $599, and for the XPS 410n, $849. With the Inspiron, you get an Intel Pentium® T2080, 512 MB memory, and an 80 GB drive; with others, an intel Core 2 Duo E4300, 1 GB memory, and a 250 GB drive.

PAY BY CELL PHONE

In case you haven't noticed, we are in the early stages of a proliferation of pay-by-phone services that will allow you to use the cell phone in place of a credit card. PayPal, Inc. (**www.paypal.com**), for example, unveiled PayPal Mobile in April, which allows users to make purchases via text messaging. Another one, and perhaps the first to be offered by a major carrier, is Obopay, which is slated to be available from Verizon Wireless (**www.verizonwireless.com**) by the time you read this (although you don't have to go through a carrier to sign up).

The service is based on a prepaid account you establish with Obopay, Inc. (**www.obopay.com**). You add money to the account from your existing credit or debit card, after which you can send money to any US mobile phone number, request money, and so on. The recipient doesn't have to be already signed up with the service at the time you send money, but it is presumable that withdrawing the cash without signing up would be problematic.

You can also get the optional Obopay prepaid MasterCard® if you need to get cash from an ATM, which, of course, somewhat defeats the purpose of the service.

It's hard to say how soon or whether this will catch on in the USA, but at least it's cheap: Sending money costs only $0.10 per transaction, and it's free to withdraw or receive. Some other fees can kick in, though, so be sure to check out the fees page on the website.

GOOGLE EARTH DRAWS CRITICISM

If you haven't signed up for Google Earth (**earth.google.com**) yet, be advised that it's a pretty impressive service as well as being free, unless you go for the Plus ($20), Pro ($400), or Enterprise (unspecified) versions. Not only do you get (depending on your location) satellite photos that zoom in close enough that you can tell a car from a truck in the driveway, you can even tilt the image to give a simulated 3D view, rotate it, and "fly" around. Not everyone is amused, however, including the head of US Air Force intelligence and surveillance, Lt. Gen. David Deptula.

The general recently expressed the opinion that such mapping software poses a security threat, although he did observe, "To talk about danger is, if I may, really is irrelevant, because it's there. No one's going to undo commercial satellite imagery."

If it's any consolation, the images don't appear to be updated very often. I can still zoom in on a neighborhood tiki bar that was torn down more than a year ago, so neither you nor Osama need worry as long as you keep moving.

CIRCUITS AND DEVICES

NUKE 'EM BACK TO NATURE

■ Billed as the world's smallest microwave, the WaveBox® works on AC or DC power.

So you're ready for the big camping trip and looking forward to getting back to nature, breathing some fresh air, and eating some tasty, outdoor-cooked food. Sounds great, but don't forget the WaveBox microwave (**www.thewavebox.com**), a product of The Frank Group, so you can nuke those Tater Tots to a nice, mushy beige. Offered as the "world's smallest microwave" (cooking cavity dimensions 10 x 7 x 6 in), it won't help much with the fresh venison you drag back to the pickup, but you can probably fit a couple squirrels inside with no problem.

Well, okay, maybe it would be convenient to have one in a car or boat, as it can be powered directly from the 12V battery via the cigarette lighter jack or alligator clips, as well as from a 120V outlet. Plus, the Wave

Box includes an integrated soft-sided cooler that fits inside to keep food cool during transport. And the things seem to be popular, as they were back-ordered as of this writing. But you can get a lot of charcoal for the $199 list price.

FANS DELIVER HIGH VELOCITIES

■ Fans offer counter-rotation and high velocity.

An interesting pair of fans — the San Ace 60 and 80 models — are now offered by Sanyo Denki Co., Ltd. (**www.sanyo-denki.com**). Available in 12V, S- and H-speed models, they are designed for use with servers, storage systems, communications equipment, and a range of industrial machinery.

The design is based on twin counter-rotating fans that produce what the company claims to be the highest airflow and static pressure capabilities in the industry. They offer a maximum airflow of 4.53 m^3/min and static pressures up to 550 Pa. Power consumption is as low as 43.2 W, with noise generation as low as 68 dB, and the rated life expectancy is 40,000 hr @ 60°C.

The San Ace 60 measures 60 mm sq by 76 mm thick, and the Ace 80 is 80 mm sq by 80 mm thick. Optional features include tach and lock rotor sensor outputs and PWM control. Even in small quantities, you can pick them up for about $40. Plan ahead, though, because delivery runs eight to 12 weeks.

COMPACT PCC FOR IGBT MODULES

Component manufacturer EPCOS (**www.epcos.com**) recently introduced a power capacitor chip (PCC) with a busbar that fits the IGBT modules of most major suppliers. The cube-like design has dimensions of 280 x 110 x 120 mm and a volume fill factor of nearly one, which is aimed to allow the design of highly compact converters.

■ The EPCOS PCC fits IGBT modules of most suppliers.

At a rated voltage of 900 VDC, the device offers a capacitance of 1,000 F (yes, farads). The ESL for the entire PCC, including the busbar, is a maximum of 15 nH. As a result, IGBT modules with steep switching edges experience negligible voltage overshoots. **NV**

INDUSTRY AND THE PROFESSION

RESEARCH SITE ONLINE

Question: What do the following organizations have in common: Acoustical Society of America, American Geophysical Union, American Institute of Aeronautics and Astronautics, American Institute of Physics, American Physical Society, American Society of Civil Engineers, American Society of Mechanical Engineers, American Vacuum Society, The Electrochemical Society, The Institute of Electrical and Electronics Engineers, Institute of Physics Publishing, Optical Society of America, Society of Automotive Engineers, Society for Industrial and Applied Mathematics, and SPIE? No, it isn't that they all offer their members cheap life insurance. The pertinent fact is that they all teamed up to create the Scitopia research site, which is quite an impressive feat of organization, as well as digital grunt work. Officially launched June 3 at the Special Libraries Association's annual conference, it is a free search portal containing more than three million documents, including peer-reviewed journal articles and conference proceedings, spanning 150 years of science and technology. The site is still in the beta stage, but if you have a question about any subject addressed by any of the above organizations, just log onto **www.scitopia.org** and ask away.

COMPUTER MUSEUM OPEN FOR BUSINESS

■ The Computer History Museum, based in Mountain View, CA, offers a look at literally tons of vintage computer equipment.

It looks a lot like your neighborhood used computer shop. It even looks a little like my garage. But neither contains as much worthless digital junk as the Computer History Museum (CHM) (**www.computerhistory.org**). Its collection encompasses about 112 international manufacturers and artifacts that once filled 7.5 40 ft oceangoing containers. The museum's holdings include nearly 50,000 objects, photographs, and films, as well as 4,000 linear feet of documentation and several hundred gigabytes of software. But if that weren't enough, SAP Global Communications, which has supported the museum from the beginning, recently donated $250,000 to allow CHM to acquire a new collection of rare computers and related items, previously slated for destruction, from a remote warehouse in northwestern Germany. So if you want to ogle some things ranging from, oh, a VIC-20 to a CDC 6600, just drop in. Admission is free.

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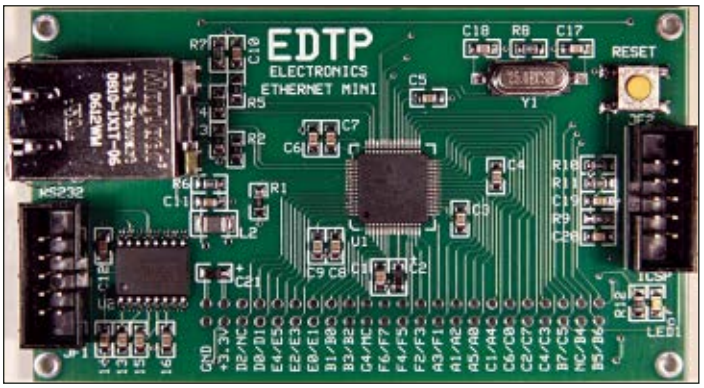
■ BY PETER BEST

REWRITING C IN PICBASIC PRO

THE C PROGRAMMING LANGUAGE HAS GROWN LIKE a creeping weed extending its branches and leaves out from the personal computer (PC) world and into the realm of the microcontroller. To put a C language program into a microcontroller, you will need a C compiler that is tooled for microcontrollers. Good C compilers are based on a set of standards that have been applied to other equal or better C compilers. Thus, C programs written with these standards-based C compilers tend to be portable between hardware platforms. For instance, it is fairly easy to port a Microchip C18 application to the ways of the HI-TECH PICC-18 C compiler. It's also light work to port any Custom Computer Services PIC C compiler application to either Microchip C18 or the HI-TECH PICC-18 C compiler. That's nice. However, the project we're about to tackle will be coded entirely in Basic. When I think of PIC microcontrollers and BASIC, an image of code splashes written with the microEngineering Labs PICBASIC PRO Basic Compiler displays for my mind's eye.

STAND AND BE COUNTED

Many of you *Nuts & Volts* readers are avid Basic programmers. I'm not privy to the *Nuts & Volts* subscriber list, but I'll bet that much of the Basic code aimed at microcontrollers found or referenced within the microEngineering Labs developer's resources forum was created by *Nuts & Volts* readers. Believe it or not, when it comes to portability, source code aimed at the PICBASIC PRO Basic Compiler can be easily redirected to and from lines of C source code. If you don't see the light now, you will by the time we're finished with this project as we will port the entire Ethernet MINI driver from HI-TECH C to PICBASIC PRO Basic.



■ PHOTO 1. We discussed this piece of hardware in the previous installment of Design Cycle. The Ethernet MINI is based on the Microchip PIC18F67J60, a stand-alone Ethernet node/microcontroller combination. You'll need to understand how this puppy works to get the most out of the porting project.

At first glance, the C-to-Basic port we're about to embark on does not look to be a walk in the park. There is a considerable amount of C source we must convert to equivalent Basic statements. As with all huge and seemingly insurmountable tasks, the key to success is to divide and conquer. We will break the porting tasks down into small chunks and logically work our way up the coding hill. However, before we begin this porting hike, it would be wise to have a plan and understand the pitfalls we will encounter along our way.

THE PLAN

We will be writing code for the EDTP Ethernet MINI (shown in Photo 1), which is based on the Microchip PIC18F67J60 microcontroller. A complete set of hardware drivers for the Ethernet MINI — which includes ARP, PING, DHCP, TCP, and UDP — has already been fielded by EDTP's Fred Eady. We will take that existing (and known working) technology and convert line by line Fred's firmware C statements to corresponding Basic statements.

In preparation for this project, I've put in some extensive searching and reading time. I'm very familiar with the Microchip PIC18F67J60. So, 99% of my research was done within the pages of the microEngineering Labs developer resources forum. I'm not totally PICBASIC PRO challenged as I have previously fielded some PICBASIC PRO-based projects. Much of my study was intended to re-familiarize myself with the PICBASIC PRO mnemonics and the ways of the Basic language.

There are many wise men and women contributing to the microEngineering Labs forum and if you're in need of PICBASIC PRO Basic Compiler help or advice, the answers lie in this forum. You can also find some very tricky PICBASIC PRO code there, as well. (See the Sources box for company websites.)

The tools we will use are standard fare. The Microchip MPLAB ICD 2 will be used to interface the Ethernet MINI to Microchip's MPLAB IDE. As I was reading through the microEngineering Labs PICBASIC PRO Basic Compiler forum, I came across a couple of posts that indicated that when "serious" PICBASIC PRO debugging was necessary, the MPLAB ICD 2 was employed. Well, we're going to get pretty serious and that's precisely why I've tapped the MPLAB ICD 2 for this project.

From the editorial point of view, using the MPLAB ICD 2 in conjunction with MPLAB IDE allows me to easily include PIC microcontroller memory dumps and watch values that I see during production into the text that you ultimately read. The EDTP shop is geared up for Microchip products, which means they have and use Microchip development tools in all of their PIC projects. I realize that you may not be equipped with Microchip factory development equipment. There is absolutely no reason why you can't deploy your personal PIC18F67J60 debugging/programming development suite. I once had a discussion with a programmer that I highly respect and he said, "It doesn't matter which language you use if your application works in the end." I feel the same way about development tools. If a suite of development products works for you, get them out and use them.

The PICBASIC PRO Basic Compiler melds nicely into the MPLAB IDE. With the MPLAB ICD 2, source level debugging and many of its options are available with this configuration. For instance, we are allowed to set break-points, examine microcontroller register and variable values, view the resultant assembler code, and look at memory areas. The triad of PICBASIC PRO, MPLAB IDE, and MPLAB ICD 2 development tools also gives us the ability to single-step through the Ethernet MINI driver source code.

Great strides have been made in microcontroller USB interfacing (kudos to Dr. Bob and his HIDMaker FS). One day, I will have to move on to microcontroller-based USB interfacing and leave the trusty RS-232 interface behind. However, as long as I can obtain and solder easy-to-use RS-232 interface ICs into my projects and run Tera Term Pro on my laptop, I'll most likely use an RS-232 interface.

In the case of the Ethernet MINI, we'll plan to activate an interrupt-driven RS-232 interface based upon the PIC18F67J60's hardware EUSART. The availability of an RS-232 interface on the Ethernet MINI provides an extra debugging tool if we choose to deploy it during our porting process. PICBASIC PRO also offers its own firmware-based RS-232-like debugging mnemonics. However, we won't plan on using the PICBASIC PRO serial debugging elements in this project. The base purpose of implementing an RS-232 port on the Ethernet MINI is to display status messages, which we will hope to see in short order.

That's the plan. Use high-visibility debugging tools and techniques to complete the C-to-Basic port. Now, let's consider the rocks that will be in our path.

THE PITFALLS

The Basic programming language has endured the test of time. I can recall sitting in my local RadioShack store (in which I was later employed) writing simple Basic programs on the newly announced TRS-80. If you consider what I was doing with the TRS-80 then versus what you and I are doing right now with this project, you'll find that I've not changed much over the years. Consider this. I was writing Basic code for a 4 MHz Z80 microcontroller in that RadioShack store. I am currently writing Basic code for a 41.6667 MHz PIC18F67J60 microcontroller in *Nuts & Volts Magazine*. Hmmmm ...

When I was banging out Ohm's Law calculations on the TRS-80, college students and engineers were banging out applications on UNIX machines using the publicity-shy C programming language. The commercial Internet as we know it today did not exist in my TRS-80 programming days and you can bet those UNIX guys and gals with their C compilers and big network of computers were hard at work laying down the foundation of the Internet we now know and love.

Obviously, Basic is a viable alternative to C as far as our Ethernet MINI driver project is concerned. Otherwise, we would not be indulging in this conversation, and we would not be wasting cycles by attempting to perform this C-to-Basic port. However, there are some things C that don't line up directly to things Basic. For instance, you can't write Basic macros that correspond to C macros because Basic macros using PICBASIC PRO don't exist. Let me qualify that last statement. Macros written with PICBASIC PRO mnemonics don't exist. Assembler macros can be threaded into PICBASIC PRO source code. I don't care whether it is C or Basic. It's the compiler's job to interpret our source statements and generate the appropriate assembler mnemonics. Thus, we won't code any assembler other than a simple NOP (No OPeration) instruction.

The only reason we will code NOPs in assembler form is that NOP is not a native PICBASIC PRO mnemonic. Since we are unable to code a C-like macro in PICBASIC PRO, we will convert all of the C macros we come across into Basic subroutines. I can see some of you cringing. I realize that a subroutine in any language is not as efficient as a macro or an assembler routine most of the time. However, that's the cards we were dealt and we'll play them as best we can.

The C programming language allows the programmer to enumerate variables automatically. Enumeration is simply the assignment of a number to each element in a set of elements with each successive element number being automatically assigned to the next corresponding element in the sequence. For instance, consider enumerating the constants A, B, and C beginning with the number 1. Constant A would be enumerated as 1, B as 2, and C as 3. Thus, the elements in this enumeration would correspond to their enumerated numeric values. Here is how enumeration was used in the Ethernet MINI C driver source code. Consider the code snippet:

```
typedef enum _DHCP_STATES
{
	DHCP_ENTRY,
	DHCP_INIT,
	DHCP_WAIT,
	DHCP_BROADCAST,
	DHCP_DISCOVER,
	DHCP_REQUEST,
	DHCP_BIND,
	DHCP_BOUND,
	DHCP_DISABLED
}DHCP_STATE_LIST;

DHCP_STATE_LIST DHCPSTATE;
```

In C and Basic, every variable has a type. The typedef keyword is used here to create a new data type name called DHCP_STATE_LIST, which is simply a name that represents the values of the enumerated _DHCP_STATES constants. Each _DHCP_STATE constant between the braces is enumerated (DHCP_ENTRY = 0, DHCP_INIT = 1, etc.). The idea of using a typedef is to make the program easier to read and understand. Thus, in this case each constant has a name associated with its enumerated value. DHCPSTATE is the actual variable that the program will use. DHCPSTATE is of type DHCP_STATE_LIST, which is defined as the enumeration _DHCP_STATES. Now that the enumerated constants have human-understandable names, we can simply check the value of the DHCPSTATE variable using simple C comparison statements like these:

```
switch(DHCPSTATE)
{
	case DHCP_ENTRY:
		printf("\r\nDHCP RESET..");
		for(i=0;i<4;++i)
			tempipaddrc[i] = 0x00;
		DHCPSTATE = DHCP_INIT;
	case DHCP_INIT:
		printf("\r\nDHCP INIT..");
		for(i=0;i<6;++i)
			svrmacaddrc[i] = 0xFF;
		for(i=0;i<4;++i)
			svridc[i] = 0xFF;
		msecs_timer = 0;
		DHCPSTATE = DHCP_WAIT;
	case DHCP_WAIT:
		if(msecs_timer >= 2000)
			DHCPSTATE = DHCP_BROADCAST;
		break;
```

Do you get the idea? We have assigned human names to the enumerated list and the constant values in the enumerated list. DHCPSTATE is an arbitrary variable name that just happens to fit here. We could have just as well designated the variable name as PETER, which would have resulted in the code that follows:

```
DHCP_STATE_LIST PETER;

switch(PETER)
{
	case DHCP_ENTRY:
		printf("\r\nDHCP RESET..");
		for(i=0;i<4;++i)
			tempipaddrc[i] = 0x00;
		PETER = DHCP_INIT;
	case DHCP_INIT:
		printf("\r\nDHCP INIT..");
		for(i=0;i<6;++i)
			svrmacaddrc[i] = 0xFF;
		for(i=0;i<4;++i)
			svridc[i] = 0xFF;
		msecs_timer = 0;
		PETER = DHCP_WAIT;
	case DHCP_WAIT:
		if(msecs_timer >= 2000)
			PETER = DHCP_BROADCAST;
	break;
```

Note that the names within the braces are constant despite what the variable name happens to be. The typedef doesn't reserve memory, which means we can create a number of variables that will use the elements of the enumeration list behind the DHCP_STATE_LIST type by simply declaring a new variable name of the DHCP_STATE _LIST type.

That's pretty fancy stuff and it's a pitfall for us. Here is what we have to code in PICBASIC PRO to build our enumerated DHCP state list:

```
;DHCP STATES
DHCPSTATE    VAR     byte
DHCP_ENTRY           CON   $0
DHCP_INIT            CON   $1
DHCP_WAIT            CON   $2
DHCP_BROADCAST       CON   $3
DHCP_DISCOVER        CON   $4
DHCP_REQUEST         CON   $5
DHCP_BIND            CON   $6
DHCP_BOUND           CON   $7
DHCP_DISABLED        CON   $8
```

The DHCPSTATE variable is a byte that is loaded with one of the constant values of the manually enumerated list of DHCP states. This is a rendition of the C language typedef gone Basic. Despite the fancy trappings of the C typedef keyword, the PICBASIC PRO DHCP STATES definitions are basically all that is taking place under the covers.

The seemingly simple DHCPSTATE case statements we've been looking at are full of PICBASIC PRO potholes. The PICBASIC PRO code that follows is the pothole filler:

```
select case  DHCPSTATE
       case DHCP_ENTRY
             hserout[13,10,"DHCP RESET.."]
             for i8 = 0 to 3
               tempipaddrc[i8] = $00
             next i8
             DHCPSTATE = DHCP_INIT
       case DHCP_INIT
             hserout[13,10,"DHCP INIT.."]
             for i8 = 0 to 5
               svrmacaddrc[i8] = $FF
             next i8

             for i8 = 0 to 3
               svridc[i8] = $FF
             next i8

             msecs_timer = 0
             DHCPSTATE = DHCP_WAIT
       case DHCP_WAIT
             if msecs_timer >= 2000  then
               DHCPSTATE = DHCP_BROADCAST
             endif
end select
```

Let's take in the converted DHCPSTATE comparison code line by line. The C switch statement must be replaced by the PICBASIC PRO select case equivalent. What you will find during the port is that most of the C braces ({}) will either be eliminated or replaced by PICBASIC PRO keywords such as end select, end if, next, and then. Parenthesis normally are not required for PICBASIC PRO keyword use but are used identically as they would be in the C language, in cases where the compiler's mathematical operator priority may override the programmer's desired execution order within a line of PICBASIC PRO source code. All of the C printf statements must be altered to the PICBASIC PRO hserout format with "13,10" replacing the C language "\r\n" carriage return and line feed characters. The C language for statements lack the next keyword required by PICBASIC PRO. Thus, we must also port all of the C language for statements to the PICBASIC PRO for/next format.

The break keyword is a necessary part of the C language switch concept. Normally, the break keyword is always used to end a case statement in C. Note the absence of break keywords in our example. The absence of the break keyword allows the logic to flow into the next case statement without first exiting the C switch function. We will have to deal with that logic as we encounter it. That could mean not using the PICBASIC PRO select case functionality in that part of the ported code.

Definitions and declarations of variables and constants are also a potential problem when porting an application of this size. I easily exceeded the PICBASIC PRO maximum number of DEFINE keywords in this first pass of the port. Consider this line of C code from the Ethernet MINI driver:

```
#define DHCP_DISCOVER_MESSAGE    0x01
```

There are a large number of these types of definitions in the original Ethernet MINI C source code. Instead of using a PICBASIC PRO DEFINE keyword in the port, I called upon the PICBASIC PRO CON keyword construct as shown in this line of ported PICBASIC PRO source code:

```
DHCP_DISCOVER_MESSAGE            CON      $01
```

Function is yet another word you won't find in the PICBASIC PRO programmer's guide when used in the context of PICBASIC PRO programming. Here is a C function that we must port to equivalent PICBASIC PRO code:

```
void wr_phy(char reg, unsigned int data)
{
       // Write the register address
       MIREGADR = reg;
       NOP();
       // Write the data
       // Order is important: write low byte first,
       // high byte last
       MIWRL = LOW_BYTE(data);
       NOP();
       MIWRH = HIGH_BYTE(data);
       NOP();
       // Wait until the PHY register has been written
       while(BUSY);
}
```

Lots of gotchas here. First of all, C functions allow the use of input variables such as the eight-bit character function variable reg and the 16-bit integer function variable data. We'll also have to deal with the macros LOW_BYTE and HIGH_BYTE here, as well. No worries. The PICBASIC PRO port follows:

```
;preload the values needed within the wr_phy subroutine
rgstr = PHCON2
data16 = $0110
gosub wr_phy             ;wr_phy(PHCON2, $0110)

wr_phy:
       ; Write the register address
       MIREGADR = rgstr;
@      nop
       ; Write the data
       ; Order is important: write low byte first, high
byte last
       MIWRL = data16 & $00FF           ;LOW_BYTE(data)
@      nop
       MIWRH = (data16 & $FF00) >> 8    ;HIGH_BYTE(data);
@      nop
       ; Wait until the PHY register has been written
       while BUSY
       wend
       return
```

On the PICBASIC PRO side, we simply turned the wr_phy C function into a PICBASIC PRO wr_phy subroutine. In this case, the original C function did not return a value to the caller. Some of the Ethernet MINI driver C functions do indeed return a value. If a return value is required, an eight-bit or 16-bit variable is declared and inserted into the ported PICBASIC PRO subroutine to

TABLE 1

Address	Symbol Name	Value
ED9	EPKTCNT	0x04
085	_packetheader	0x54
2FB	_packet	0x00
03A	_rxlen	0x4E

■TABLE 1. I punched up the necessary Watch variables to get me to the potential data I hoped to receive from the laptop PINGs. The Watch window also allows the programmer to see directly into the PIC18F67J60's Ethernet registers. I wish I had that capability when I was writing the initial ENC28J60 driver.

LISTING 1

```
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\FE>ping 192.168.1.150

Pinging 192.168.1.150 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 192.168.1.150:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Documents and Settings\FE>ping 192.168.1.150

Pinging 192.168.1.150 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 192.168.1.150:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Documents and Settings\FE>ping 192.168.1.150

Pinging 192.168.1.150 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 192.168.1.150:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Documents and Settings\FE>arp /all

Displays and modifies the IP-to-Physical address translation tables used by
address resolution protocol (ARP).

ARP -s inet_addr eth_addr [if_addr]
ARP -d inet_addr [if_addr]
ARP -a [inet_addr] [-N if_addr]

  -a             Displays current ARP entries by interrogating the current
                 protocol data.  If inet_addr is specified, the IP and Physical
                 addresses for only the specified computer are displayed.  If
                 more than one network interface uses ARP, entries for each ARP
                 table are displayed.
  -g             Same as -a.
  inet_addr      Specifies an internet address.
  -N if_addr     Displays the ARP entries for the network interface specified
                 by if_addr.
  -d             Deletes the host specified by inet_addr. inet_addr may be
                 wildcarded with * to delete all hosts.
```

continued ...

mimic the C function returned value. The original C function input variables are replaced by the variables rgstr (an eight-bit value whose name is short for register) and data16 (a 16-bit value). The PICBASIC PRO subroutine variables are preloaded before the call is made to the PICBASIC PRO subroutine.

The original Ethernet MINI driver C source is full of C comment tags (//) which must all be converted to the PICBASIC PRO comment tag (;). The global replacement capability offered by the MPLAB IDE source code editor comes in handy for this job. However, one must be careful as the global replacement utility can be really dumb and change things you don't want it to touch. The C NOP statements can also be globally mutated with the same comment tag replacement caveat holding true.

Another feature of the C programming language is its inclusion of pointers. The closest we get to a pointer in PICBASIC PRO is an array. So, C pointers — which are preceded by the '*' character — are emulated with values within variables on the PICBASIC PRO side of the port. For example, a C-to-PICBASIC PRO byte pointer conversion will typically look like this:

```
char *bufferptr         //C pointer
==
bufferptr var byte    ;PICBASIC PRO
                       ;pointer
```

There are many other C language concerns we must engage and conquer and, if we have not already discussed them, I will address them as we come to them in the process of the port. Not everything we will have

■ LISTING 1. ARP and IPCONFIG are good friends to have when you're tracing through who's who in IP and MAC land. The commands that you will use most are arp — a, which dumps the PC's ARP cache and IPCONFIG /all, which spills the PC's important network information.

to deal with will be related to the nuances of C or PICBASIC PRO. I'll leave you with a bug that ate my lunch and licked the pail. Can you see what is wrong with this line of code? It compiles perfectly:

```
MIWRH = (data16 & $FF00) > 8
;HIGH_BYTE(data)
```

This is what happens when you sit at the porting table a few days too many. Here is what that "good" line of code should look like:

```
MIWRH = (data16 & $FF00) >> 8
;HIGH_BYTE(data)
```

I caught this as I single-stepped through the wr_phy subroutine. I was looking to find out why the high byte of the integer stored in the data16 variable wasn't being read back correctly after I supposedly loaded it correctly. The greater than (>) and right shift (>>) operators are identical in C and PICBASIC PRO. The error occurred when I manually entered the greater than operator (>) incorrectly instead of the right shift operator (>>). The PICBASIC PRO code I manually and incorrectly entered was to replace the C macro HIGH_BYTE(data), which is used all over the place. So, to save some keystrokes, I copied the incorrect line of code into every HIGH_BYTE(data) macro line in the PICBASIC PRO ported code. Enough said.

STAGE 1

So far, I've successfully ported the EUSART driver and the PIC18F67J60 initialization driver. I've also ported all of the arrays, pointers, constants, and macros associated with the ported driver components. There is just enough code to bring the Ethernet MINI online.

To test my work up to this point, I also ported and enabled the get_frame function, which loads an incoming frame into the Ethernet MINI driver's packet memory. Since

Listing 1 continued ...

```
  -s             Adds the host and associates the Internet address inet_addr
                 with the Physical address eth_addr.  The Physical address is
                 given as 6 hexadecimal bytes separated by hyphens. The entry
                 is permanent.
  eth_addr       Specifies a physical address.
  if_addr        If present, this specifies the Internet address of the
                 interface whose address translation table should be modified.
                 If not present, the first applicable interface will be used.
Example:
  > arp -s 157.55.85.212   00-aa-00-62-c6-09  .... Adds a static entry.
  > arp -a                                     .... Displays the arp table.

C:\Documents and Settings\FE>arp

Displays and modifies the IP-to-Physical address translation tables used by
address resolution protocol (ARP).

ARP -s inet_addr eth_addr [if_addr]
ARP -d inet_addr [if_addr]
ARP -a [inet_addr] [-N if_addr]

  -a             Displays current ARP entries by interrogating the current
                 protocol data.  If inet_addr is specified, the IP and Physical
                 addresses for only the specified computer are displayed.  If
                 more than one network interface uses ARP, entries for each ARP
                 table are displayed.
  -g             Same as -a.
  inet_addr      Specifies an internet address.
  -N if_addr     Displays the ARP entries for the network interface specified
                 by if_addr.
  -d             Deletes the host specified by inet_addr. inet_addr may be
                 wildcarded with * to delete all hosts.
  -s             Adds the host and associates the Internet address inet_addr
                 with the Physical address eth_addr.  The Physical address is
                 given as 6 hexadecimal bytes separated by hyphens. The entry
                 is permanent.
  eth_addr       Specifies a physical address.
  if_addr        If present, this specifies the Internet address of the
                 interface whose address translation table should be modified.
                 If not present, the first applicable interface will be used.
Example:
  > arp -s 157.55.85.212   00-aa-00-62-c6-09  .... Adds a static entry.
  > arp -a                                     .... Displays the arp table.

C:\ >arp -a

Interface: 192.168.0.100 --- 0x3
  Internet Address      Physical Address      Type
  192.168.0.1           00-14-bf-9a-2e-41     dynamic

C:\ >arp -s 192.168.0.150 00-00-45-44-54-50

C:\ >arp -a

Interface: 192.168.0.100 --- 0x3
  Internet Address      Physical Address      Type
  192.168.0.1           00-14-bf-9a-2e-41     dynamic
  192.168.0.150         00-00-45-44-54-50     static

C:\ >ping 192.168.0.150

Pinging 192.168.0.150 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 192.168.0.150:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
```

BUFFER DUMP 1

```
Address   00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F      ASCII

  2F0     8C CE 0B 32 59 4D 7B 17 DF 89 CD 00 00 45 44 54 ...2YM{. .....EDT
  300     50 00 11 25 18 0A DB 08 00 45 00 00 3C 4A 9C 00 P..%.... .E..<J..
  310     00 80 01 6D DA C0 A8 00 64 C0 A8 00 96 08 00 3D ...m.... d......=
  320     5C 03 00 0D 00 61 62 63 64 65 66 67 68 69 6A 6B \....abc defghijk
  330     6C 6D 6E 6F 70 71 72 73 74 75 76 77 61 62 63 64 lmnopqrs tuvwabcd
  340     65 66 67 68 69 07 18 DF 2B 41 43 41 43 41 43 41 efghi... +ACACACA
  350     43 41 43 41 00 20 45 46 45 45 46 45 46 41 43 41 CACA. EF EEFEFACA
  360     43 41 43 41 43 41 43 41 43 41 43 41 43 41 43 41 CACACACA CACACACA
  370     43 41 43 41 42 4F 00 FF 53 4D 42 25 00 00 00 00 CACABO.. SMB%....
  380     00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ........ ........
  390     00 00 00 00 00 00 00 11 00 00 21 00 00 00 00 00 ........ ..!.....
  3A0     00 00 00 00 E8 03 00 00 00 00 00 00 00 00 21 00 ........ ......!.
  3B0     56 00 03 00 01 00 00 00 02 00 32 00 5C 4D 41 49 V........ ..2.\MAI
  3C0     4C 53 4C 4F 54 5C 42 52 4F 57 53 45 00 0F 00 80 LSLOT\BR OWSE....
  3D0     FC 0A 00 53 4E 4F 4F 50 00 00 00 00 00 FC 40 A1 ...SNOOP ......@.
```

■ BUFFER DUMP 1. Don't worry. We won't be reading dumps all of the time. When we start porting the protocol modules (TCP, UDP, etc.), I'll break out the Network General Ethernet Sniffer.

I have not yet ported the ARP and DHCP drivers, I had to cheat to get results. Take a look at Listing 1, which is a printout of the actual commands I entered in a Windows XP command prompt window.

A Linksys router based at 192.168.0.1 and set up as a DHCP server networks my laptop and the Ethernet MINI. I issued the command to display the contents of the laptop's

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1 GHz Spectrum Analyzer / Function Generator
AT5011 $1225.00
AT5010 $1025.00
AT5010B $875.00

AS-5001 Mini Automatic Reflow Oven $798.00

SZM7045TR Trinocular Microscope
with Double Bar Boom Stand $590.00
with Single Bar Boom Stand $515.00

QK5020 20 MHz 2-Channel Analog Oscilloscope $250.00

ZD-9556 Orbital Shaker $265.00

ARP cache (arp -a). At this point, only the Linksys router is cached by the laptop (192.168.0.1). Since the Ethernet MINI's IP and MAC addresses are not in my laptop's ARP cache, my laptop will issue an ARP request to the Ethernet MINI before issuing the ICMP Echo (PING).

To fake out my laptop and prevent it from issuing an ARP request to the Ethernet MINI, I preloaded my laptop's ARP cache with the Ethernet MINI's IP and MAC addresses (arp -s). After checking the laptop's ARP cache to see if my static entries made it in, I PINGED the Ethernet MINI. As you can see in Listing 1, the four PINGS went unanswered as there is no ICMP code running on the Ethernet MINI yet.

At this point, I really don't care about answering the PINGs as I'm jumping up and down in the EDTP shop with excitement. I'm jumping around looking at the contents of Table 1, which is the text from my MPLAB IDE Watch window. The EPKTCNT register in the MPLAB IDE Watch window registers 0x04 representing all four ICMP Echo messages from the laptop, which are now stored in the PIC18F67J60's receive buffer. I also have a reasonable receive length value returned in the rxlen variable. This is good.

I added the packet and packet_header array watch entries to get the beginning addresses of the arrays. We won't take a close look at the packet_header array as it has already given us some good information via the rxlen variable, which is filled from the packet length slot of the packet_header array. The proof in the pudding is shown in BufferDump 1. The presence of the alphabet in the packet clues me that this may be an ICMP packet without going any further. Just for grins let's pick through the dump and see if I am right.

The first thing we should receive is the destination hardware (MAC) address which, in this case, is the Ethernet MINI's MAC address. Just so happens that beginning at offset 0x02FB in BufferDump 1 you can make out the Ethernet MINI's MAC address (00 00 45 44 54 50). The sender's MAC address should immediately follow and it does as my laptop's MAC address is 00 11 25 18 0A DB. Offset 0x0312 is equal to 0x01, which indicates that this is an ICMP packet. The sender's IP address (my laptop IP address) should be located at 0x0315 (C0 A8 00 64 or 192.168.0.100) and the receiver's IP address (the Ethernet MINI's IP address) should immediately follow (C0 A8 00 96 or 192.168.0.150). Another immediate clue to me that I had a chance of having caught a good packet is the presence of "SNOOP" in the buffer area. SNOOP is my laptop's network name.

SOURCES

■ *HI-TECH* (**www.htsoft.com**) — HI-TECH PICC-18 C compiler

■ *microEngineering Labs* (**www.melabs.com**) — PICBASIC PRO

■ *Microchip* (**www.microchip.com**) — MPLAB ICD 2; MPLAB IDE; PIC18F67J60

■ *EDTP Electronics, Inc.* (**www.edtp.com**) — Ethernet MINI

THE NEXT CYCLE

Now that we know we can receive Ethernet frames, all we have left to do is automate the dump parsing process we just performed on BufferDump 1. I'll post the ported portion of the PICBASIC PRO Ethernet MINI driver source code for you on the *Nuts & Volts* website (**www.nutsvolts.com**). You may also get the code package from the EDTP website (**www.edtp.com**).

When we meet again, we will spin up the Design Cycle to port and bring up the ARP and UDP modules so we can port and enable the Ethernet MINI's DHCP engine. **NV**

CONTACT THE AUTHOR

■ *Peter Best can be reached via email at peter@nerdvilla.com.*

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Our #1 Mini-Kit for 35 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Used throughout the world as the first learning kit for students young and old! Great solder practice kit. Runs on 3-15 VDC.

BL1 **LED Blinky Kit** **$7.95**

Cricket Sensor

Not only does it chirp just like a real cricket, it also senses temperature and changes the chirp accordingly. Can actually determine temp by chirps! Squishing under your feet voids warranty! Runs on 9VDC battery. Speaker included.

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Electronic Siren

Exactly duplicates the upward and downward wail of a police siren. Switch closure produces upward wail, releasing it makes it return downward. Produces a loud 5W output, and will drive any speaker! Horn speakers sound the best! Runs on 6-12 VDC.

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Universal Timer

Build a time delay, keep something on for a preset time, provide clock pulses or provide an audio tone, all using the versatile 555 timer chip! Comes with circuit theory and a lots of application ideas and schematics to help you learn the 555 timer. Runs on 5-15 VDC.

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SA7 **RF Preamp Kit** **$19.95**

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Dries any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 **Touch Switch Kit** **$9.95**

Walking Electronic Bug

Built around a pair of subminiature cell phone motors, this bug wanders around looking for things to bump into! Sensors below his LED eyes sense proximity and make him turn away! Steer him with flashlights too! Runs on two "N" batteries.

WEB1 **Walking Bug Kit** **$29.95**

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

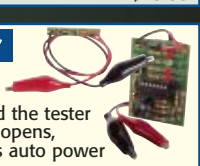
MB1 **Mad Blaster Warble Alarm Kit** **$9.95**

DTMF Encoder Decoder

Decodes standard Touch Tones from telephones, radio, or any audio source. Detects and decodes any single digit and provides a closure to ground up to 20mA. Great for remote tone control Runs on 5VDC.

TT7 **DTMF Encode/Decode Kit** **$24.95**

Cable Polarity Checker



Checks continuity AND polarity of a pair of wires! Simply connect the remote board to one end, and the tester to the other end and LED's show opens, shots, and polarity! Even includes auto power off! Runs on a standard 9V battery.

MK132 **Cable Polarity Checker** **$7.95**

Water Sensor Alarm

This little $8 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump!). When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 **Water Sensor Alarm Kit** **$7.95**

RF Actuated Relay

Just what you need when adding a preamp or power amp in line with an antenna! Auto senses RF and closes an on-board DPDT relay that's good to UHF at 100W! Also great to protect expensive RF test equipment. Senses as low as 50mW! Runs on 10-15VDC.

RFS1 **RF Actuated Relay Kit** **$19.95**

Light Actuated Switch

Tired of turning your lights off? This little kit auto senses light and automatically closes the on-board SPDT relay. Light sensitivity is adjustable and a delay circuit prevents recycling. Relay contacts are rated at 5A. Runs on 12-15VDC.

MK125 **Light Actuated Switch Kit** **$7.95**

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Add time delay power-off to any of your projects or circuits! Momentary push button selects desired time delay (1H, 2H, 4H, 8H, 24H) and LED flashes faster as time approaches. On-board 10A relay. Runs on 120/240VAC.

K8075 **Power Saver Timer Kit** **$24.95**

IR Remote Control Checker

Is your IR remote control working? Just point and shoot, and this kit will let you know! Confirms IR signal generation from any IR remote and displays proper receipt on the four LED display. Don't change the batteries, check the remote first! Runs on a standard 9V battery.

MK137 **IR Remote Checker Kit** **$6.95**

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SBRGB1 **SMT Multi-Color Blinky Kit** **$29.95**

SMT High Intensity Blinky

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- ✔ **Great for air shows**
- ✔ **Patented circuit and design!**

Written Up In Communications Magazines Worldwide!

For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the plane you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. ***At an air show! Just imagine listening to all the traffic as it happens***
2. ***Onboard aircraft to listen to that aircraft and associated control towers***
3. ***Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)***
4. ***Commercial pilots to monitor ATIS and other field traffic as needed at their convenience***
5. ***General aircraft monitoring enthusiasts***

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals! We have you covered on that one. The ABM1 has no local oscillator, it doesn't, can't, and won't generate any RF whatsoever! That's why our patent abstract is titled "Aircraft band radio receiver which does not radiate interfering signals". It doesn't get any plainer than that!

SPECIFICATIONS

Frequency Range:	118 MHz to 136 MHz
Receiver Type:	Patented Passive Detector
IF Frequencies:	None!
Receiver Sensitivity:	Less than 2 uV for detectable audio
Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled
Power Requirement:	9VDC battery
Dimensions:	2.25" x 2.8" PC Board 2.5" x 4.6" x .9" Case
Weight:	4 oz. with battery

Even with its compact design, we designed the ABM1 for easy construction by the electronic hobbyist. Thru-hole parts are used for all customer assembly. Several SMT components are part of the circuit, and they are pre-installed at the factory! In addition, a factory assembled and tested SMT version with additional shielding for adjacent channel overloading is also available for the aircraft professional that just wants to get listening quickly. Stereo earbuds are even included! If you're a private pilot, commercial pilot, airport worker, aircraft enthusiast, attend air shows, or spend a lot of time in airports or onboard aircraft, the ABM1 is for you!

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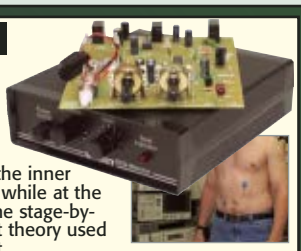

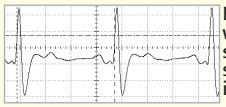

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ECG1WT	**Factory Assembled & Tested ECG1**	**$89.95**
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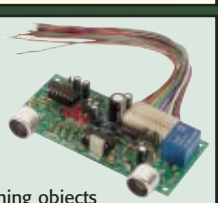
- ✔ **1A on-board relay!**
- ✔ **Factory assembled, ready to go!**



A 40kHz ultrasonic beam measures the distance to oncoming objects and warns you in several different modes. A buzzer output provides a fast, slow, or continuous audible output. Relative distance is displayed with a 3-bar LED graph display. An alarm indication is provided by an LED indicator as well as a set of NO/NC relay contacts. Features adjustable alarm distance and a range of 7" to 8'. Output relay NC/NO relay contacts are rated at 1A low voltage. If you're looking for a proximity or presence sensor for a project or application, this is the perfect choice. Just interface it into your project and you're all set! Runs on 12VDC at 200mA max.

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ **RC Eliminator.**
- ✓ **Capacitor Question.**
- ✓ **Audio Amp.**

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

MIXER CIRCUIT

Q As you may know, dual gate JFETs/MOSFETs have been phased out, and those that can be found are very expensive. Somewhere I have seen a circuit that duplicates, say a 3N201 or a 40573 being used as a mixer in a receiver, using two MPF102s. I would appreciate a circuit, if possible.

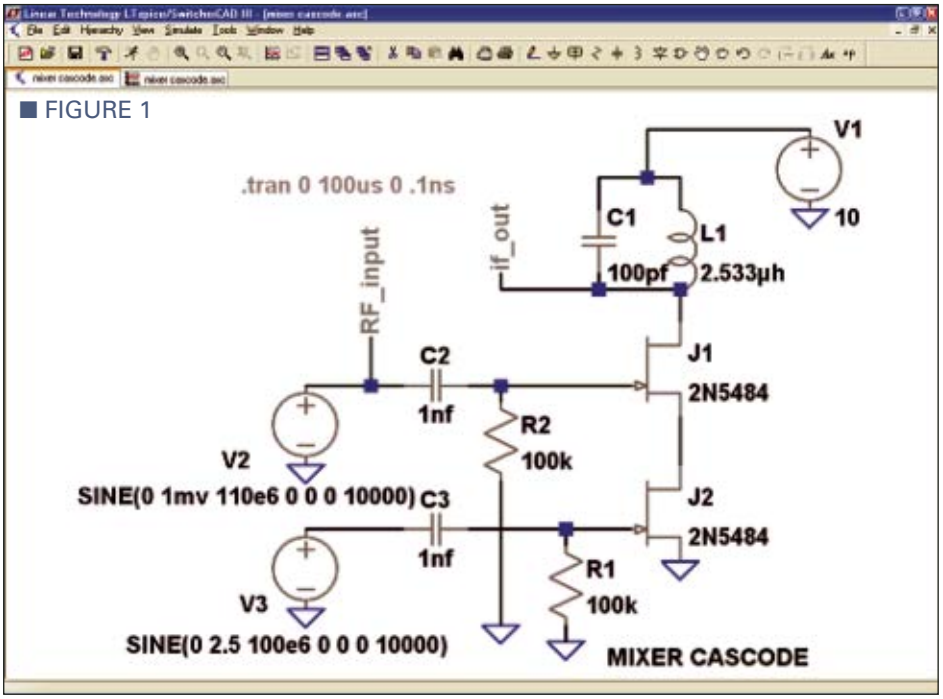
— Barry J Maloney

A I was not aware that dual gate FETs were being phased out. I think it is that thru-hole parts are not in demand because the electronic world is going to surface-mount. I found three dual gate MOSFETs presently available: BF1211, BF908, and BF991, all in SMD packages.

A mixer consists of a non-linear device which handles two signals of different frequency. The output has the original two signals plus the sum and difference frequencies. A filter is required at the output to select the desired frequency, usually the difference frequency. A diode makes a good mixer but the best you can do is -6 dB gain from RF input to IF output. An XOR logic gate can also be used as a mixer within its frequency range.

Your request for a two transistor circuit brought a cascode circuit to mind, so I threw together the circuit of Figure 1 in the LTspice simulator. The RF input to J1 is 2 mV peak-to-peak at 100 MHz; the local oscillator (LO) input to J2 is five volts p/p at 110 MHz. The output circuit is tuned to the difference frequency of 10 MHz. Figure 2 is the output signal. The 10 MHz is about 70 mV p/p, a gain of over 30 dB. The LO output is significant, more filtering is needed.

■ FIGURE 1



A single transistor can be used as a mixer and oscillator at the same time, but the problem is that a strong RF signal can "pull" the LO off frequency, causing increased interference and reduced gain. This problem increases as the RF and LO signals get closer together.

There is a lot of interest nowadays in balanced mixers which will reject the LO signal, making the output filtering easier. A single balanced mixer rejects just the LO, a double balanced mixer rejects both the RF and the LO. Figure 3 is a single balanced mixer. The input transformer is center-tapped to provide push-pull drive to the output transformer, through the JFETs. The local oscillator drive is common mode and does not couple to the output. The output transformer must be well balanced, such that when the same signal is applied to both sides, the result is cancellation. As you can see in Figure 4, there is no LO in the output waveform. The 10 MHz is 70 mV peak, a gain of over 36 dB.

I used the 2N5484 because it was

in the library; it is similar to the MPF102, and costs 11 cents.

AUDIO AMP

Q I have a KIA6221AH 30W BTL dual audio power amp chip. I was thinking of using it to hook directly to my TV dish audio output for music. Do you have suggestions on a schematic or better choice of amp? I can find the data sheet, but it is a test circuit and needs a volume control.

— Terry T.

A The gain of the KIA6221AH is internally set, but you can vary it with an external resistor. The stability is a function of gain, so it is not advisable to use this as a volume control. The schematic given is pretty much the recommended one and there is not enough data provided to vary from that by much. The most you can expect to get out is 10 watts per channel at low distortion.

With 4 ohm speakers, the RMS voltage output (assuming the data sheet uses RMS power and not some meaningless "music equivalent") is E = sqrt(40) = 6.3 VRMS. The peak voltage for a sine wave is 8.9 volts but music is not sinusoidal; even so, a 12 volt supply looks okay. The filter caps for a transformer-rectifier power supply will be humungous, so I recommend a switching supply. Mouser part number 680-MSM6012 will be very reliable at $61.19, or 552-PSA-60-112-R at $34.93 is more economical.

The signal from your TV dish output should be line level (about one volt) so you don't need a lot of gain. A gain of 10 (20 dB) should be sufficient, but to be sure I set the gain at 30 dB (X32). Using the formula on the data sheet, Rf = 1,300 ohms. Rf is R2 and R4 on the schematic in Figure 5. I used the same cap values as used for 40 dB gain on the data sheet; I don't think it will have any affect other than bringing the low frequency response down to lower frequencies.

There are not a lot of parts; you could mount them on perf board, being careful to keep the A and B power grounds separate from the preamp and input grounds. Connect the grounds together as close to the power supply as possible. You will need a heatsink for the IC, because a linear amp is 50% efficient, at best. If the amplifier is capable of 20 watts output, it must be able to dissipate 20 watts, also. Crydom model HS-1 looks good. It has tabs so you can mount it vertically and bolt the IC to it.

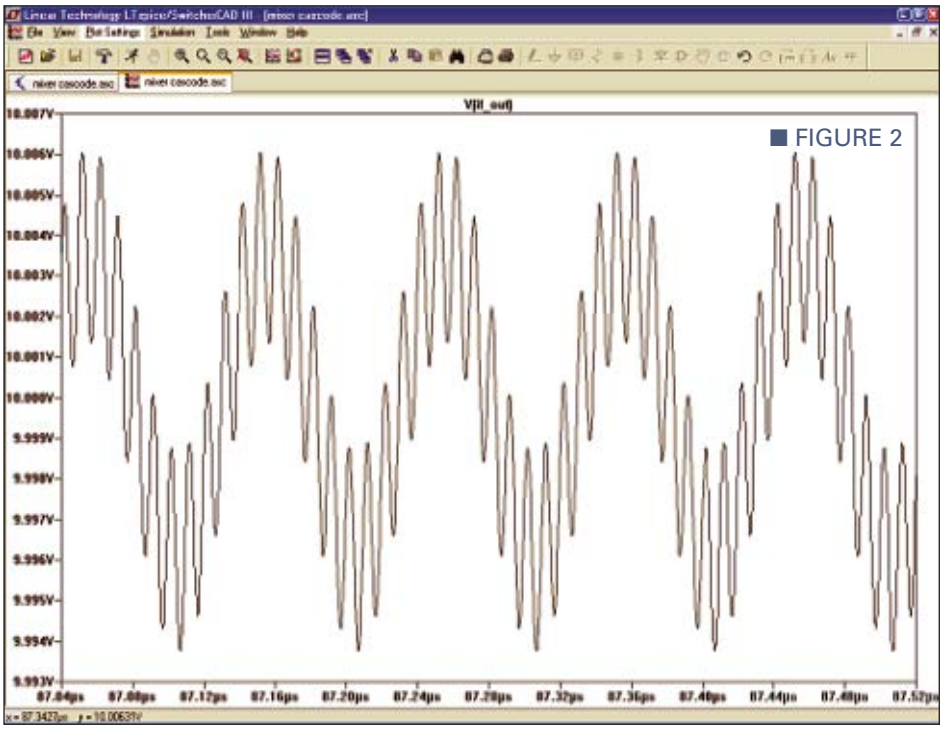


FIGURE 2

I want to keep the temperature rise down to 60 degrees C at 20 watts, so that means the thermal resistance should be 60/20 = 3 degrees C per watt. The HS-1 is 2.5 degrees C per watt so it will work without a fan. The heatsink is for a solid-state relay, so you will need to drill and tap holes to mount the IC. The HS-1 is available from Allied Electronics, part

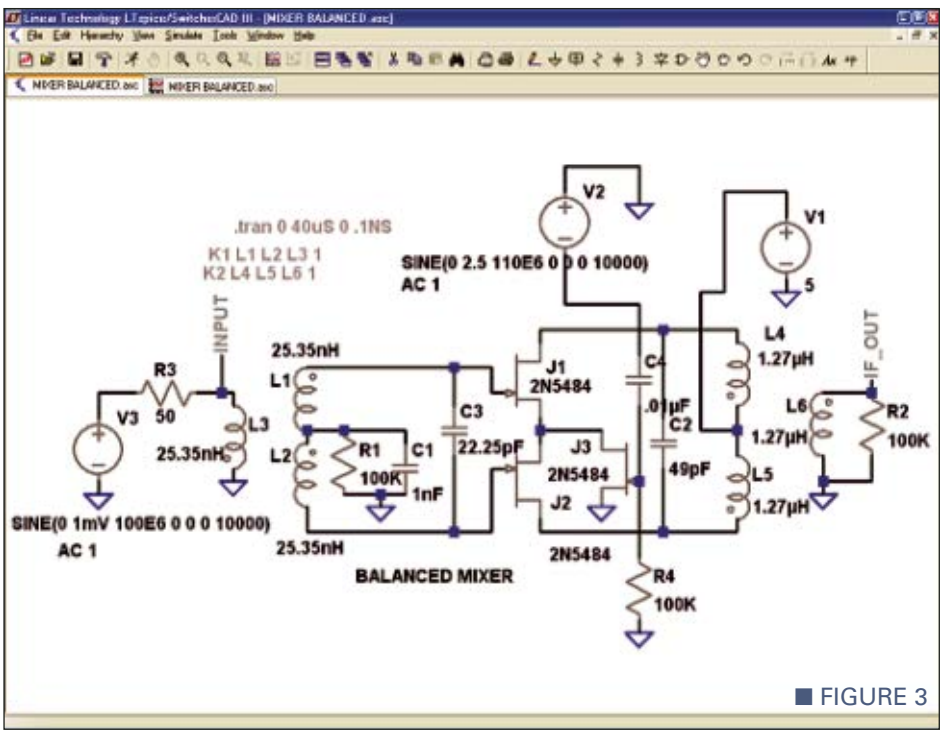


FIGURE 3

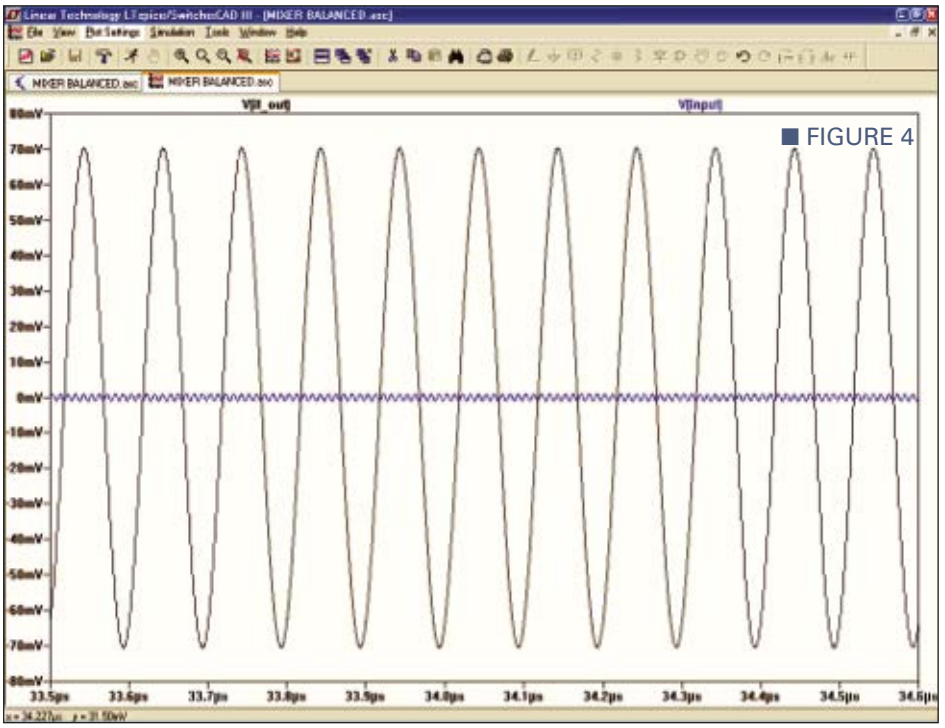


FIGURE 4

number 682-0063; cost is $7.89.

SIMULATION SOFTWARE

Q I have been looking everywhere for electronic simulation software for the PC, but most of the software out there is for educational institutions, and it costs an arm and a leg for the software and licensing fees. I want design software which allows a simulation to view the result of the circuit, i.e., an LED turning on or off. It must have testing tools such as an oscilloscope or multimeter. Could you recommend a software similar to SPICE but within a reasonable price range for an electronics student?

— Anonymous

A A Google search for "free schematic capture spice" will turn up many possibilities, but most of them are limited in circuit size or output in order to entice you to buy the full-up version. The only free, full feature simulator that I am aware of is LT Spice/SwitcherCad III from Linear Technology. The downside is that the library has only Linear parts in it, but you can import other models or make your own. Go to **www.linear.com** and download the program for free. If you have trouble using LT Spice, the folks at the *Nuts & Volts* online forum will help you out. Spice originated at UC Berkley and at one time was free. Probably still is.

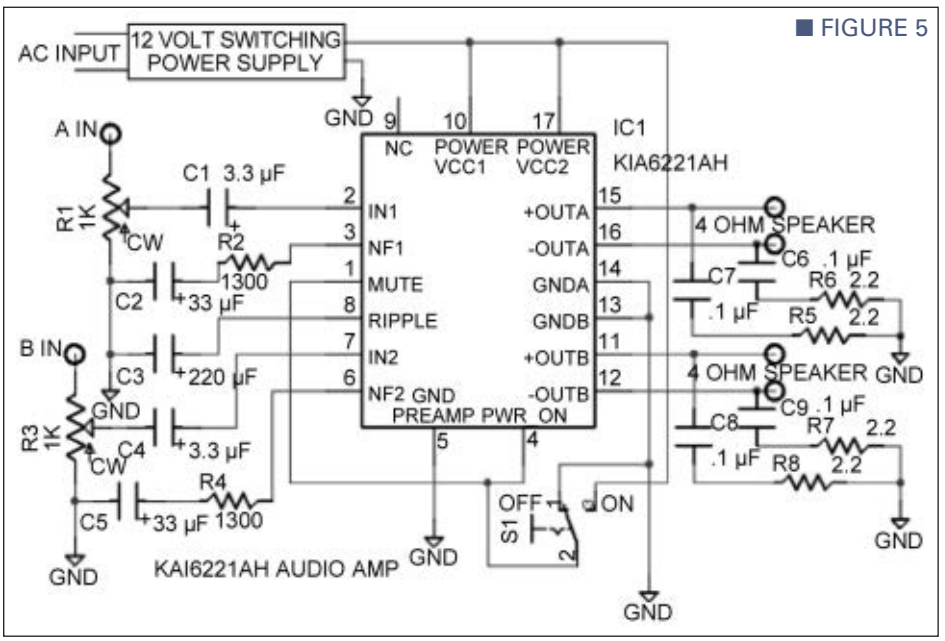


FIGURE 5

CAPACITOR QUESTION

Q What is the best way to figure the correct size of electrolytic capacitors to use on a DC power supply? I have seen commercial power supplies with both single and multiple sets of capacitors and have always wondered why there is a difference and what are the benefits of both designs?

When multiple capacitors are used, should they be of different sizes? If this topic has already be addressed in a previous issue, please let me know where to look.

— Bill Blackburn

A I am sure the subject has been covered before, but it does not hurt to repeat it. Filter caps perform two important functions: smoothing the input pulses from the rectifiers, and absorbing pulses from the load. Aluminum electrolytic capacitors are good at 120 Hz, but not so good at 100 MHz. Ceramic or film capacitors work best at high frequency, so two types should be used in the power supply. Short leads are important at high frequency; the film or ceramic caps should be right at the power supply output terminals. The size of the smoothing cap depends on the output current. A rule of thumb is 80,000 µF per amp for 100 mV ripple. Or, use this equation:

$$C = I*dT/dE$$

where C is the capacitance in farads, I is the current in amps, dT is the time between pulses in seconds, and dE is the peak ripple voltage in volts. This equation will also tell you how large a bypass cap is needed for high frequency.

All capacitors have an equivalent series resistance (ESR). Film and ceramic caps have such a low ESR that it is generally not specified on the datasheet, but electrolytic caps have significant ESR that can cause overheating due to ripple current. For this reason, multiple caps are used in parallel.

Another factor for using parallel caps is that ripple current times ESR creates a ripple voltage that can only be reduced by using a cap with lower ESR or parallel caps. It turns out that it is more economical to use multiple parallel caps rather than one low ESR cap of the same total value. When using parallel caps, they should all be the same, otherwise the current will not divide equally between them.

Another factor that TJ Byers had covered recently is that a capacitor will become series resonant with its lead wires at some frequency. The cap impedance is a minimum at resonance but is inductive above resonance, so the impedance increases with frequency. The datasheet will give you an idea where the resonance will occur, but since it is entirely dependent on lead length and layout, choosing the cap becomes an art.

PULSE WIDTH	EFFECT
1 ms	Engine shuts down, throttle pot has no effect
1.3 ms	Lowest speed, minimum pot position
1.5 ms	Middle speed range, middle pot position
2.0 ms	Maximum speed, maximum pot position

■ TABLE 1

R/C ELIMINATOR

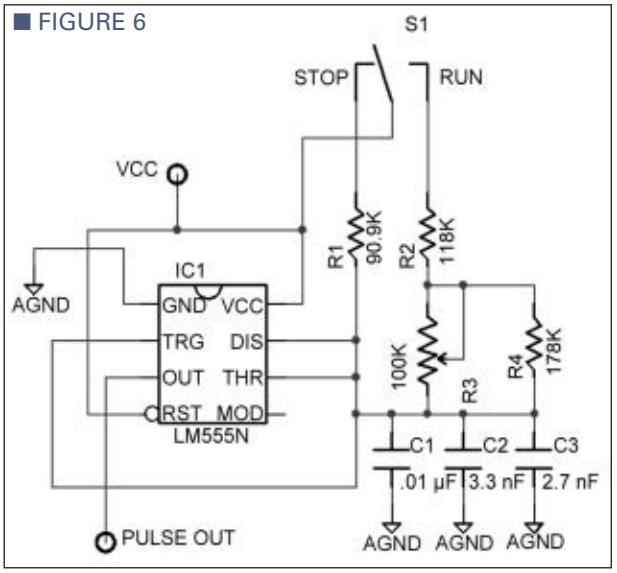
Q I would like to build a radio eliminator that can be used instead of an R/C transmitter and receiver. As I am sure you already know, a radio eliminator is used to prevent the transmission of a radio signal while checking out the operation of an R/C servo. There are lots of servo cycler circuits available on the 'net using the 555 chip and a potentiometer, but they fall short when used to control a throttle channel. They do not have a properly set up switch to shut down an engine.

Refer to Table 1. The lowest pulse width should be 1 ms and the highest 2 ms. We should have one potentiometer for throttle control and one toggle switch for shutdown.

If the stop switch is moved to the off position, the output signal must go to 1 ms and the throttle potentiometer has no effect on the output signal.

— Anonymous

■ FIGURE 6



A I know nothing about R/C systems, but I think I understand the problem. In the circuit in Figure 6, the on-off switch takes the pot out of the circuit and substitutes a fixed resistor for 1 ms pulse width. If the switch is a make-before-break type, there may be several high frequency pulses before going to 1 ms. If the switch is break-before-make — which is typical of toggle switches — there may be a gap in the pulse train. When only one 555 is used, the frequency varies with the pulse width. Two 555s could be used to have a constant frequency, but since the variation is less than 2:1, I did not think it is necessary. **NV**

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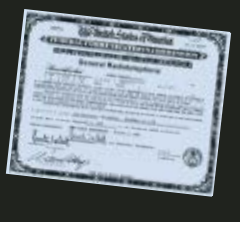

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TALKING BATTERY CHARGER

Interacter, Inc. — a leading US manufacturer of industrial battery chargers, based in Meriden, CT — announces the new Talking Battery Charger module.

The majority of warranty failures of batteries are due to incorrect charging. Warranty claims and repair calls are preventable if the operator can be reminded to charge the battery promptly after use. But the operator may not read the instructions. The Talking Battery Module provides speech prompts to remind the user to recharge the battery when needed. It announces battery status so the user knows if the battery is charged, and when the battery is low.

The module is self-contained and simple to install with just two wires to the battery. It can be mounted in the battery pack, in the charger, or control panel. It can be supplied pre-fitted into a battery charger or as a stand-alone module.

Applications include materials handling equipment, emergency lighting, backup power supplies, medical devices, marine equipment, or anywhere battery power is used that is subject to lack of attention to charging. Internal jumper links configure the module to work with batteries of a 12V, 24V, or 36V system voltage. A complete starter kit is currently available for approximately $49.

The module includes a signal output connector which can drive an external relay or signal to indicate battery discharged, automatically disconnect the load, or to drive red/green panel indicator lamps to indicate battery status.

Various voice options are available to replace the standard English pronunciation (wav files are stored in a plug-in EEPROM). Custom wav files can be loaded into the module for OEM customers to announce the company name every time the power is turned on.

For more information, contact:
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ZIGBEE™ DEVELOPMENT TOOLS

Ember Corporation — a ZigBee™ Alliance member — and CCS, Inc., are teaming up to launch the CCS Development Kit for wireless applications using Microchip PIC® microprocessors. This low-cost development platform includes the Ember EM260 ZigBee™ network co-processor and the EmberZnet ZigBee™ stack on CCS prototyping boards to be used with the CCS C Compiler.

The CCS Wireless-Ember ZigBee Edition Development Kit enables fast prototyping of ZigBee applications. The EM260 integrates an IEEE 802.15.4 radio, a network processor, and onboard memory to run a complete ZigBee network protocol stack. The EM260 reduces a product's cost, size, and power consumption with its inexpensive small package size, and twice the wireless range of competitors.

The CCS development kit will be sold for a limited time at the price of $599 and includes sink board (with EM260 module) with the PIC18LF4620, sensor boards (with EM260 modules) with the PIC16LF886, CCS PCWH C Compiler, in-circuit debugger/programmer, exercise book, batteries and cables needed, and all required royalty free software source. The Ember USBLinks programmer for the EM260 will be sold separately at CCS.

For more information, contact:
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CLONE REMOVER

Moleskinsoft has announced the release of version 2.3 of Moleskinsoft Clone Remover — an efficient utility designed to search for various duplicate files on your PC and delete unnecessary file copies. Moleskinsoft Clone Remover 2.3 finds duplicate files of different types, including music (MP3), image files, ZIP and RAR archives, and others. The utility allows you to save time by looking for similar files and deleting them. It will also help to free extra space on your PC and make it work faster.

Version 2.3 expands the functionality of Moleskinsoft Clone Remover, allowing the user to discover and delete files of different types simultaneously, applying different methods of search for each type of file. Basically, Moleskinsoft Clone Remover employs five different ways to find duplicate files. First, the utility can find similar files with different names using a search by content. A search by MP3 tag is used for finding duplicate music files. The utility compares tracks by artist, name, album, year, comment, and genre. It can also compare several tags at a time. The search by properties method lets users find duplicate files by name and/or size.

When the search for duplicate files is finished, the program will show a list of found files that can be deleted immediately. To make sure that the result is correct, it is possible to open the found files with another program or view them with a built-in viewer.

Continued on Page 31

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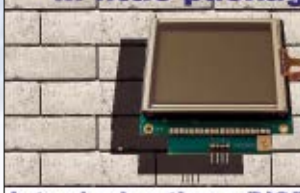

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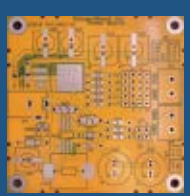

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Search results can be saved to a text file and it is possible to pause searching at any time. There is a wizard-style interface that will take you through all the stages of finding duplicate files and then operating them in a step-by-step manner. Funny pictures of cute encouraging moleskins and simple prompting questions are added for extra help. A free version for evaluation can be downloaded at **ww.moleskinsoft.com/download/CloneRemover2_setup.exe**. Moleskinsoft Clone Remover 2.3 requires Microsoft Windows 98/NT/2000/2003/XP/Vista and costs $32.90 for a single-user license. Further information on the utility, as well as its free trial version, is available on the website.

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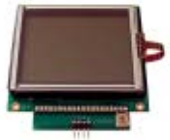
USER INTERFACE SOLUTION



Multilabs announces the release of the ezDISPLAY Mini. The ezDISPLAY Mini is a serial command controlled LCD module with an integral touchscreen. The LCD has a resolution of 128 by 64 pixels and can display both graphics and text. The touchscreen is a resistive type screen such as the types used on PDAs and the like. This allows the ezDISPLAY Mini to track the position of the touchscreen down to the pixel. The integral controller breaks down the complex decoding operation of the touchscreen and returns a simple X and Y position. The LCD is also provided with an LED backlight that can be turned on and off with a simple command. The ezDISPLAY Mini comes with two font sets: 8 x 8 and 6 x 8. A complete built-in ASCII character set and space to create 32 user-defined characters is provided in each font set. All user-defined characters are stored in non-volatile memory so they are not lost when power is removed. Memory is also provided to store up to four screens that can be reloaded at any time. These saved screens are stored also in non-volatile memory. Characters and graphics can be inter-mixed on the screen and characters can be placed in landscape or portrait mode, along with other options. The ezDISPLAY Mini has a command that allows downloads of screens from other sources such as those drawn on a computer.

The ezDISPLAY Mini comes with a floating character that companions the touchscreen. The floating character can be displayed and moved around anywhere on the screen without destroying any of the image on the LCD. This adds another level of character display to the ezDISPLAY Mini. The floating character can either be controlled by the end-use or it can be "latched" to the touchscreen so it automatically follows the movement of the user stylus or finger.

Communications to and from the ezDISPLAY Mini are done through the TTL level asynchronous serial lines. The communication baud rate is set by the user through the ezDISPLAY Mini auto baud rate detection feature. The baud rate can be in the range of 300 to 115.2K. The ezDISPLAY Mini comes with four mounting holes for secure placement. A four-pin header is used to supply power and access the serial communication lines.

For more information, contact:
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THIS MONTH'S PROJECTS

Build a Better Mouse Trap 32

Flight Recorder 38

Waveform Generator 42

LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

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●●○○ . . . . Intermediate Level

●●●○ . . . . Advanced Level

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CONTROL YOUR WORLD

Build a Better Mouse Trap. For Real.

I moved out of the city years ago and now live in the country in an old farm house. We have three barns and suffer quite a bit of damage from the local mouse population. I have used several types of traps with varying amounts of success.

Being the provincial inventor, I decided to design my own mouse trap.

In deciding how to build a better mouse trap, I came up with the following requirements:

- The trap must capture the mouse unharmed.
- The trap must run on four AA rechargeable batteries.
- The trap must run for at least one month before the batteries must be charged.
- The trap must sound an alarm once a mouse has been caught.
- The trap must work in any kind of lighting conditions.
- The trap must hold the mouse until it can be released into a safe location.

I wanted to build something that could be easily duplicated with readily-available parts so that others could build the same or similar trap. In this article, I will show you two variations of my mouse trap. The first uses a PC to monitor the trap and to sound an alarm. The second is totally self-contained.

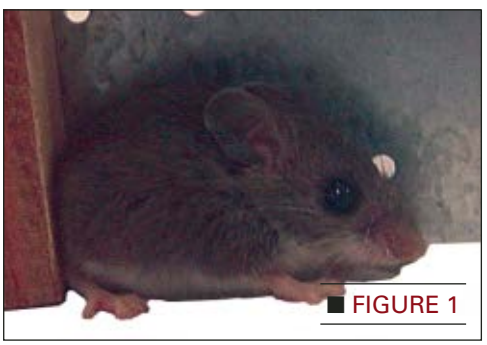


FIGURE 1

Mechanics

For both traps, the mechanics are the same. Several ideas came to mind such as trap doors, swinging doors, and sliding doors. I decided on a dropped door. With this type, you have a heavy door which slides in a groove. The door is suspended by a pull pin that when pulled, allows the door to fall, blocking the opening.

The actual door is made out of a steel truss plate that measures 5-3/4" x 7". You can pick these up at any home center. The particular one I am using is a Simpson TP57.

You will need to create a groove in a couple pieces of wood to act as a track to hold the door in place. This can be done with a table saw or by sandwiching and gluing up a few pieces of wood.

If you are still having trouble picturing what I am trying to describe, think of a guillotine but not quite so deadly. Figure 2 shows one of the guides I built.

FIGURE 2

FIGURE 3

Next, you will need some sort of mechanism to hold the door in place until it is tripped.

Figure 3 shows a small pull pin that I created that holds the door in place until the pin is pulled. The pin is a piece of thin brass tubing about

3/32″ in diameter. The pin must be able to slide through one of the holes in the truss plate as shown in Figure 4.

The pin is attached to the end of a piece of nylon string (fishing line). Knot the end of the line and pull it through the tubing. A small drop of hot glue will help secure it.

Originally, I thought about some sort of light and sensor, but I wanted something a bit more passive that would not place any additional drain on the battery. What I came up with was a balanced plate made out of the same truss material as the door.

I soldered a 7/32″ brass tube across the width of the truss as shown in Figure 5. The tubing is not exactly in the center, but about 1/4″ toward the back of the truss. When flipped over, this creates a kind of shallow teeter-totter effect. The heavier side will face the trap opening. The idea is to place bait on the high end near the edge. When the mouse enters the trap, it walks up the ramp and as it passes the pivot point, the ramp tips.

A second brass tube is hot glued to the base of the trap near the rear. This tube sets under the high end of the teeter-totter so when the ramp tips, it makes contact with this tube. Notice the wire that is soldered to the tube. This is connected to the Vss side of the interface. The brass tube connected to the ramp is connected to the input port on the interface. The input port on our interface is held high. Tipping the ramp forces the input port low.

The rest of the trap is all a matter of taste and the materials you have on hand. Some key points for this kind of trap: Make the trap enclosure so that it is only slightly larger than the width of your ramp as shown in Figure 6. This will keep the sneaky critters from bypassing the ramp. Remember the food itself has weight and should be used to help counter-balance the trap. When I place my food on the high end of the ramp, I start in the middle and slide it back until the ramp is almost ready to trip. This allows you to adjust the sensitivity of the trap.

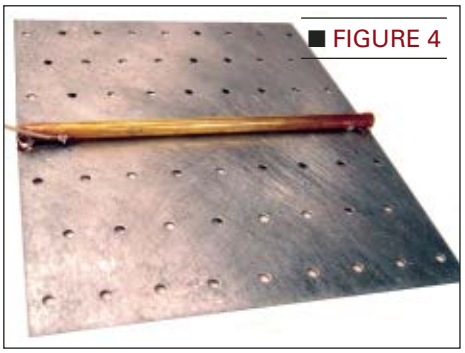


FIGURE 4

FIGURE 5

I used 1/8″ Plexiglas and plywood for my trap. Strips of precut pine would also work. It is all held together with screws. I have found that the use of transparent materials makes the trap more inviting to the mice. They probably think they have an easy escape.

Servos

In order to trip the trap, we need to pull the pin out of the door, causing it to fall. There are a couple ways you can use a servo to pull the pin. Let's take a look at both a VEX servo and a normal servo.

VEX Servo

The fishing line I used was about 4-1/2″ long with the pull pin on one end and the other end connected to a brass tube that is attached to a VEX servo via a #6 machine screw as shown in Figure 7.

My servo implementation was a bit overkill as the servo only needs to pull the pin about 1/4″. You could have just knotted the end and placed it between a couple of washers to work. To properly place the servo, raise the door and put the pull pin in place. While holding the pin in place, move the servo back until the line is taunt. The pull pin should be sticking through the door about 1/16″ or so. I used doublesided tape to hold my servo in place.

Standard Servo

The standard servo is much easier to use than the VEX. You will need a servo arm; just about any type will do. Cut all the points off the arm but one. Place the arm near the center position of the servo as shown in Figure 8. Notice that we can use small angle brackets to mount the servo or double stick tape.

With the servo placed near the center position as shown in Figure 9 tie off the line. The pin end of the line should be sticking through one of the holes holding the door in place. Don't worry if you don't get it perfect as you can always go back and retie the line.

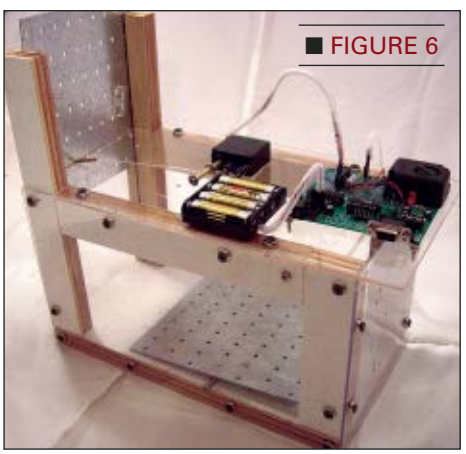


FIGURE 6

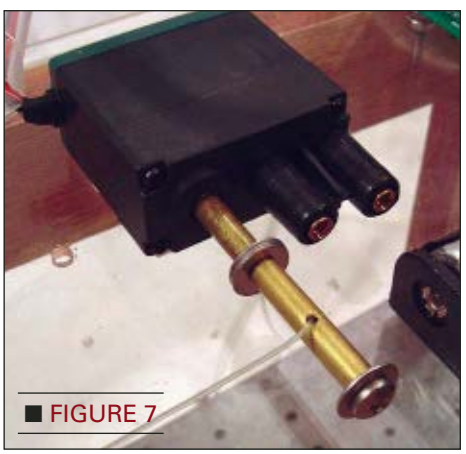
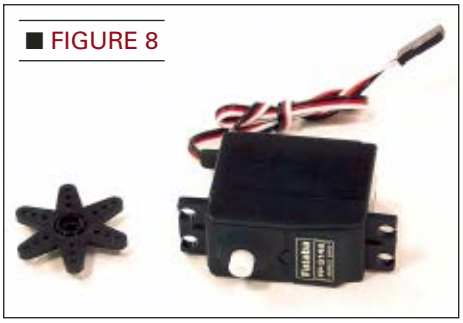
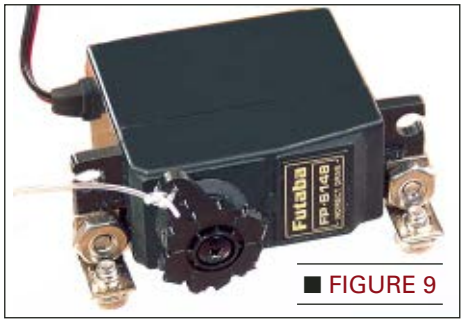


FIGURE 7

■ FIGURE 8





■ FIGURE 9

Electronics

As I mentioned earlier, I am going to show you two different types of interfaces.

SSC-32 Interface

I got my hands on a SSC-32 servo controller (Figure 10) for another project I was working on. At $39.95, this is the best darn servo controller I have ever used. It has a built-in RS-232 driver so it can be connected directly to the PC or controlled via a microcontroller.

What makes this servo controller so great is that it will control up to 32 servos via a very simple interface. You can set the time the servo takes to create its programmed move or even send commands so that groups of servos can be controlled, all creating their movement over a predefined period of time. While we won't be using any of these advanced features in our mouse trap, we will be accessing one of the other cool features. The SSC-32 has four inputs that can be read independently of any of the servos.

I used the default power configuration on the SSC-32 which allows a single battery to supply power to the servos and the logic. Lynxmotion also sells a small, pre-wired power harness that has a power switch and R/C stick battery connector as shown in Figure 11. I'm not going to show a schematic for the SSC-32 interface as it is very simple:

- Apply power source to **VL** leads.
- Plug servo into **Servo 0** position.
- Connect ramp leads to the **B and -** header.
- Connect PC serial to nine-pin connector.

Note that I used a 2,000 mAh stick battery, but you can use the same four cell battery pack that I used on the Athena interface and it will work just as well. You will have to charge the batteries more often, though.

To control the SSC-32 we will use Zeus. Zeus is a simple programming language that specializes in interface design. I have included a special, free version of Zeus called ZeusNV along with the source code and compiled applications available on the *Nuts & Volts* website (**www.nutsvolts.com**). So even if you are not the best programmer in the world, you have lots of choices here.

To quickly test your mouse trap, place the MouseTrap_DT.exe file along with the mouse.jpg and scream.wav and run the file.

If your PC is already connected to the SSC-32 and it is powered up, the servo should arm. This means that it should be slightly forward. When the trap is tripped, the servo arm will pull back then move back into the armed position.

Have fun and play around with the program. The source is called MouseTrap.txt.

Athena Stand-Alone Interface

While the PC controlled trap is cool to play with and fun to test, it is not very practical in the long term for a few reasons:

- A 2,000 mAh battery powering the SSC-32 will only last a couple days.
- You'll need to tie up a PC or laptop.
- You need to tether the mouse trap to the PC.

With this interface, we will use a very inexpensive Athena microcontroller.

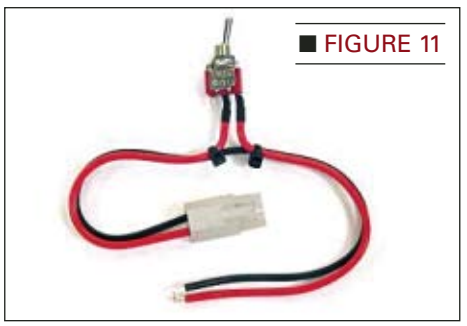
The Athena has a sleep state that uses very little power when configured properly. I built a light monitoring circuit that uses an Athena that has been running on a single set of alkaline batteries for over two years. The problem is the servo. Even with no signal being sent to the servo, it still uses quite a bit of power. This drastically shortens the battery life, so I had to come up with some way to remove the power from the servo when it was not in use.

Kronos Robotics sells some relays that can be connected directly to a microcontroller. They have a built-in diode that protects the microcontroller from any EMF generated by the coil. They are in a 14 pin DIP packages so they work with a standard 14 pin DIP socket. I used one of these relays to remove the power from the servo when not actually moving the servo.

Schematic 1 shows the complete schematic that I used. If you want to add an alarm to the circuit, simply place it across the power leads connected to the servo. That way, when the relay turns on power to the servo, it will also sound the alarm.

There are several sirens you can use for the trap. The one I used has a

■ FIGURE 10



■ FIGURE 11

sound level of 90-100 dB.

With the circuit shown in Schematic 1, you will get at least one month of continuous use with one set of rechargeable batteries. While I have successfully used alkaline batteries, they will deliver about 6V when new. This is .5V over the rated voltage of the Athena. While I have yet to blow an Athena this way, it is not recommended. If you use rechargeable batteries, you will get 4.8V to 5V from a freshly charged set. It's something to keep in mind.

Note that the schematic shows a VEX servo. You can use a standard servo, as well.

R1 is the two ohm resistor connected between the servos Vdd and the relay. This will keep the servo from resetting the microcontroller when first fired.

Note that a .1 µF and a 100 µF capacitor should be connected to Vdd and Vss as close to the microcontroller as possible.

The SPST switch (S1) is not necessary if you use a header and jumper to provide power to the circuit, as you can just remove the jumper when you want to disable the system.

I used an Athena WorkBoard PCB, as it provides ample prototype space to connect the siren and relay. After I placed my servo, I attached the battery and circuit board to the top of the trap as shown in Figure 6.

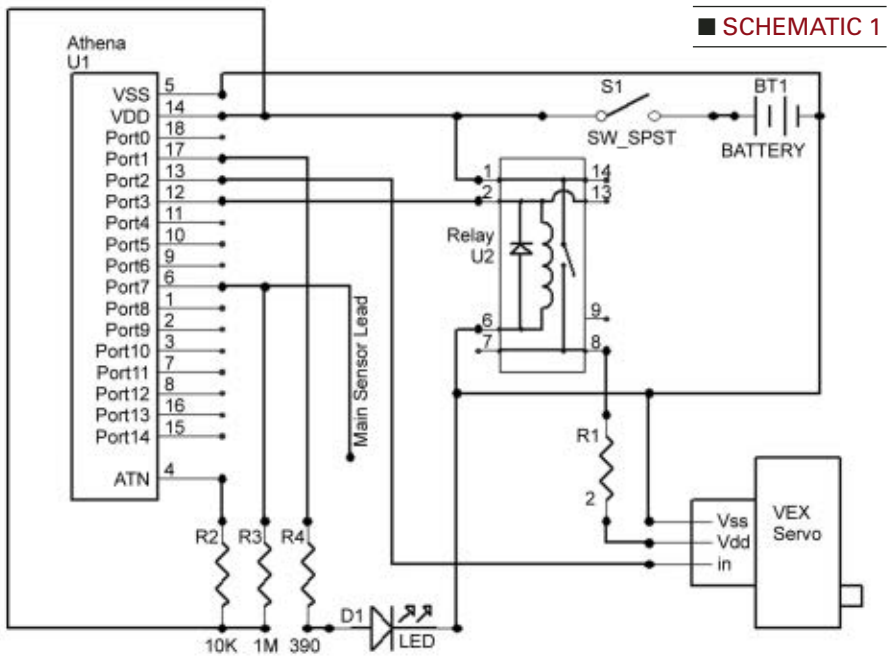
If you use one of the Kronos Robotics boards that has a built-in RS-232 driver, remove it during normal operation, as it is not needed. This will help reduce battery drain.

Program

Refer to Listing 1. The program is straightforward. It sets up the I/O ports, then arms the servo by adding a slight amount of slack to the line.

The main loop puts the microcontroller to sleep. The short from port 7 to Vss will wake up the microcontroller.

■ SCHEMATIC 1



Once awake, it activates the servo by pulling the pin, then pauses a bit and rearms the servo. It does not technically arm the servo since the pin is pulled, but it does arm the sensor. This allows the siren to keep sounding as the mouse moves up and down the ramp.

The Athena source is called AthenaMouse.txt and is included in the download.

How Well Does it Work?

In the first week, I caught 12

WEB LINKS

■ Kronos Robotics
www.kronosrobotics.com

■ KR Micros
www.krmicros.com

■ Lynxmotion
www.lynxmotion.com

■ Tower Hobbies
www.towerhobbies.com

■ Control Your World Forum
www.kronosrobotics.com/forums/viewforum.php?f=21

PARTS LIST

ITEM	PART NO.
Part no. from Kronos Robotics unless noted otherwise.	
❑ Athena Microcontroller	16276
❑ Athena WorkBoard PCB	16460
❑ Athena WorkBoard Basic	16473
Note the following components can be picked up at any electronics supply house.	
❑ Relay	16461
❑ LED	16234
❑ 4AA battery holder	16323
❑ 2 ohm 3 watt resistor	16197
❑ 390 ohm resister	16190
❑ 10K resistor	16193
❑ 1M resistor	16196
❑ .1 µF capacitor	16198
❑ 100 µF capacitor	16202
❑ Siren	16329
The Athena compiler is available free at the Kronos Robotics website.	
❑ Standard Servo from Tower Hobbies **www2.towerhobbies.com/cgi-bin/wti0001p?&I=LXUK84&P=ML**	
❑ SSC-32	Lynxmotion #SSC-32
Wire harness	Lynxmotion #WH-01

mice. I have an enclosed patio and that seems to be the main mouse thoroughfare for most of the mice scoping out my house.

One of the barns on my property is a good distance away from the house. It is not used, so it makes a good place to relocate the mice once I catch them.

An experiment I plan to do is to tag the mice and let them go at various distances away from the house to see how many make it back.

Keep in mind when working with wild mice, you need to wash your hands after handling any thing that comes in contact with the mouse or feces.

If you must handle the mouse, use gloves. Wild mice are in no way as tame as the ones you see in the pet stores. They can also be quite crafty.

Bait

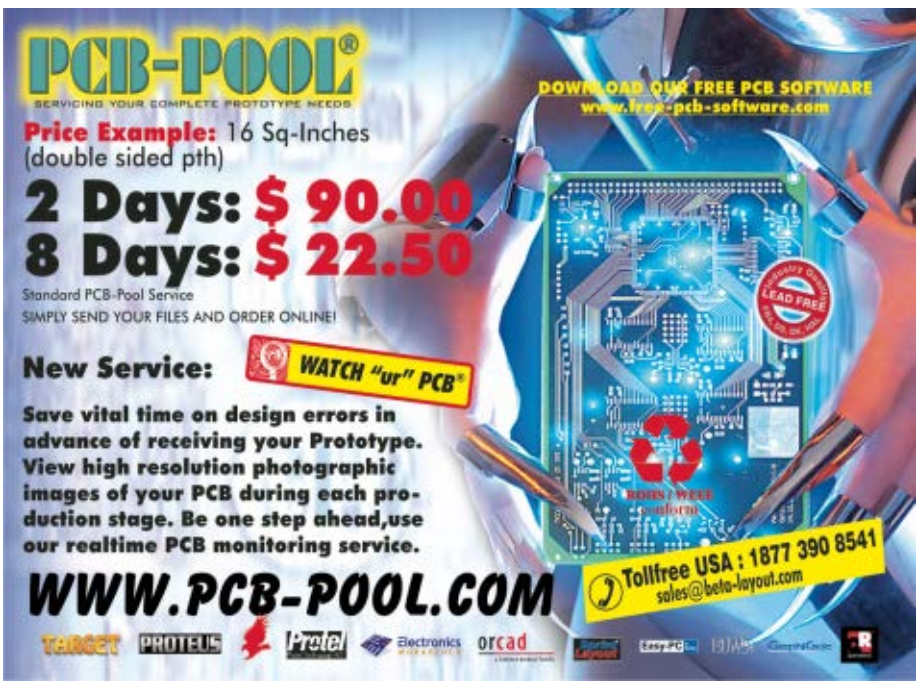
Here are a few suggestions on bait:

- Peanut butter
- Oats (oatmeal)
- Chocolate
- Water
- Pretzels

Don't use cheese as it dries out too fast. I use a combination of peanut butter with small chocolate graham cracker pieces and oats. Try other ingredients if these suggestions don't work for you. Be sure to visit the Kronos Robotics website for more information and updates. **NV**

Listing 1

```
'AthenaMouseTrap Program

  dim x
  RCSTA=0
  configio 0,1,2,3,4,5,6,8,9,10,
   11,12,13,14
  Gosub ArmServo
  gosub blink
  p7irq 3

loop:
  sleep
  gosub ActivateServo
  longpause 250,8
  Gosub ArmServo
  Gosub blink
  goto loop

ActivateServo:
  high 1
  high 3

  for x = 0 to 20
     Servo 2,80
     pause 20
  next
  low 3
  return

ArmServo:
  high 3

  for x = 0 to 20
     Servo 2,200
     pause 20
  next
  low 3
  return

'Let us know its armed
blink:
  for x = 1 to 20
    high 1
    pause 2
    low 1
    pause 50
  next
  return
```



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Linear Technology				✓
Lite-On	✓			✓
Maxim Semiconductor		✓	✓	✓
Micron Technology				✓
Microsemi				✓
National Semiconductor		✓	✓	✓
NEC Corporation	✓			✓
Philips Semi			✓	✓
Renesas Technology				✓
Sharp Microelectronics	✓			✓
ST Micro	✓	✓	✓	✓
Texas Instruments	✓	✓	✓	✓
Toshiba				✓
TOTAL	12	14	14	26

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FLIGHT RECORDER FOR MODEL ROCKETRY

PART 1

Amateur rocketry is a well established activity that is currently divided into two main categories: high-power and model. Of those participants certified to operate high-power rockets, many launch complex payloads (e.g., inertial sensors, GPS receivers, and video cameras),

but the vast majority of launches still fall into the lower power/cost model category that has traditionally provided less opportunity to experiment with airborne instrumentation.

The flight recorder described in this article is compact and light enough to be used with even small model rockets. It can be easily programmed to interface with a range of sensors and store data in non-volatile memory, for post-flight export to a PC spreadsheet for display and analysis.

Model Rocketry

It is now possible to purchase model rocket kits capable of reaching speeds in excess of 200 kph and an altitude of over 500 meters, together with disposable engines from local hobby stores. Figure 1 shows the configuration of a generic single stage model rocket that would cost around $20.

A disposable solid fuel engine is mounted in the base of the airframe and ignited electrically to initiate an automatic sequence. When the propellant burns out, a delay charge produces tracking smoke (but negligible additional thrust), allowing the rocket to coast near to peak altitude and minimum speed before the delay charge eventually ignites the ejection charge.

This final charge directs a burst of gas into the airframe to eject the nose cone and deploy the recovery chute. Elastic cord is normally used to keep the whole assembly together during the descent phase. Estes Corporation (**www.estesrockets.com**), a leading manufacturer of engines and kits, provides a wealth of useful technical information about model rocketry on its website, including the essential safety procedures for operating model rockets.

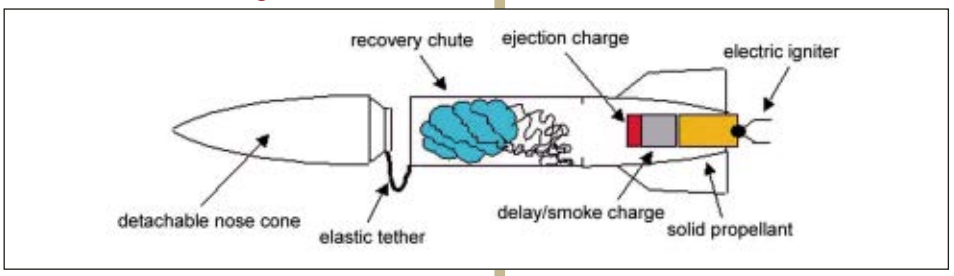
The Flight Recorder

My main design objective was to produce a development tool for speedily evaluating the latest generation of MEMS and smart sensors onboard small model rockets. The compact flight recorder design shown schematically in Figure 2 is equipped with a programmable 'sensor port' that can be easily configured in Basic to interface with a range of analog and digital sensors.

In addition to a regulated supply and digital lines, the sensor port (J4) has three (10-bit) analog-to-digital converters (ADC) and an I^2C serial bus. Apart from the three low-pass analog filters, these lines connect directly to the interface ports of a PICAXE-18X microcontroller.

The PICAXE range of microcontrollers are Microchip PIC devices

■ FIGURE 1. Generic model rocket configuration.



that are sold pre-programmed, with a bootstrap loader, by Revolution Education Ltd (REL). This proprietary code allows a PICAXE to be repeatedly re-programmed in Basic using a PC-based editor (download it free at, **www.picaxe.co.uk**).

The REL version of Basic supports many dedicated interface commands (readadc, serout, writei2c, and readi2c, etc.) that greatly simplify the development of sensor interface software. The PICAXE-18X can execute approximately 20,000 Basic commands a second and store about 600 lines of code onboard internal Flash memory. In-circuit programming is normally performed using a simple three-wire interface to a PC serial port.

A Ramtron FM24CL256 non-volatile FRAM device is used to store flight data. The low power CL version of this 32,768 x 8 bit memory operates over a supply range of 2.7V-3.6V and has an I^2C interface that can operate at a maximum bus frequency of 1 MHz. The flight recorder can write data to memory at a rate of over 500 samples per second, continuously for about a minute.

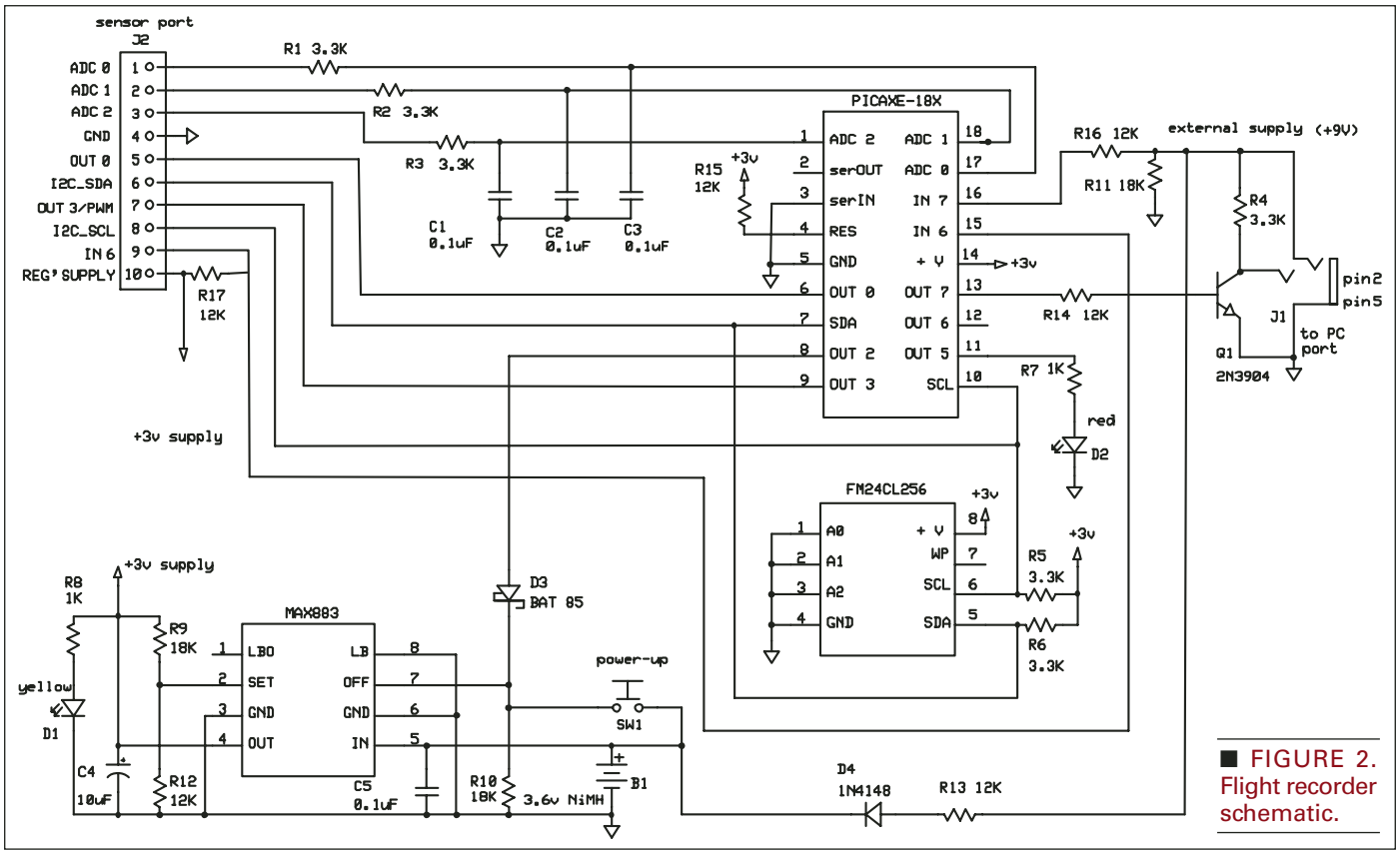
This performance would normally be sufficient for observing a complete model rocket flight from lift-off to touch-down. Stored data can be downloaded to a PC at 9.6K baud via a two-pole jack socket (J1). Because the flight recorder operates from a 3V supply, a transistor (Q1) is included to increase the serial output level above the RS-232 threshold. This is achieved by powering the collector pull-up resistor (R4) from an external 9V battery supply.

An important consideration when designing a lightweight rocketry payload is the choice of power source. For this application, a small PCB-mounted 15 mAh battery proved more than capable of supporting a number of flights before re-charging. At the flight recorder's modest 5 mA consumption, the voltage from the Ni-MH battery remains flat over most

FRAM Storage

Ferroelectric Random Access Memory (FRAM) chips are pin compatible with their more established EEPROM and Flash counterparts, but use a completely different type of non-volatile storage technology that offers a number of operational advantages. These include an increased (10 billion) read/write cycle life, together with higher write speeds and noise immunity. Compared with using EEPROM or Flash storage, the amount of software code needed to interface with a FRAM device is less because data does not have to be formatted into blocks before writing.

FRAM can be used as simply as non-volatile SRAM but without the complication of battery back-up. Ramtron International Corp. (**www.ramtron.com**) offers a wide range of parallel and serial FRAM products. A leading example is the eight-pin FM25L512 that has storage capacity of 512Kb and an SPI bus speed of 25 MHz.



■ FIGURE 2. Flight recorder schematic.

■ FIGURE 3. Flight recorder installed in the nose cone of a model rocket.

of its useful life. It was therefore possible to employ a single 3.6V cell to power a low dropout linear regulator. This combination provides similar efficiency to a switching regulator, but without the potential noise problems. The regulator's output is set at 3V by the potential divider R9/R12 and the battery is charged from the external supply via a diode (D4) and a series resistor (R13).

Flight recorder operation is initiated by pushing a power-up button (SW1), which momentarily turns on the MAX883 regulator that applies power to the rest of the electronics. When the microprocessor powers up, it latches the regulator on (via diode D3) and then enters either the trigger or playback routines, depending on whether a PC serial connection is detected at pin IN7. When a recording run or download sequence is completed, the microprocessor removes the latch and allows the regulator to power-down. Current is therefore only drawn from the internal battery in short bursts.

Two LEDs are provided that enable the operator to monitor the status of the flight recorder when the rocket is ready for launch. The yellow LED (D1) confirms the regulator has been latched on by the microprocessor and that the electronics are powered. The red LED (D2) flashes to indicate that the trigger routine is running and that the state of the 'launch switch' is being continuously monitored. The launch switch can simply be a reed switch, connected between pins 9 and 4 of the sensor port, which opens when it moves away from a fixed magnet when the rocket leaves the pad. This action allows input IN6 to be pulled high, which triggers a recording run and turns off the red LED.

Data is relatively safe while onboard the flight recorder because it can be retained in the un-powered FRAM for a period of years. In addition, the download procedure is non-destructive and can be repeated in the event of a problem at the PC end of the communications link. During a download, the red LED and the yellow LED are continuously illuminated and then extinguished when the flight recorder powers down. The risk of over-writing data from the last flight (by accidentally pushing the power-up button while the download/external power cable is disconnected) can be reduced by practicing a few pre-flight recording and download cycles using a dummy launch switch.

Construction

Figure 3 shows the prototype flight recorder installed in a 6.5 cm diameter nose cone (with the serial port, LEDs, and power-up button visable at the edge of the board). The electronics were constructed on stripboard using mostly thru-hole components. The width of the board was constrained to 3 cm to allow the flight recorder to be installed in the nose cone of smaller model rockets. However, the tallest components must be mounted along the board's center line in order to fit within a circular cross-section.

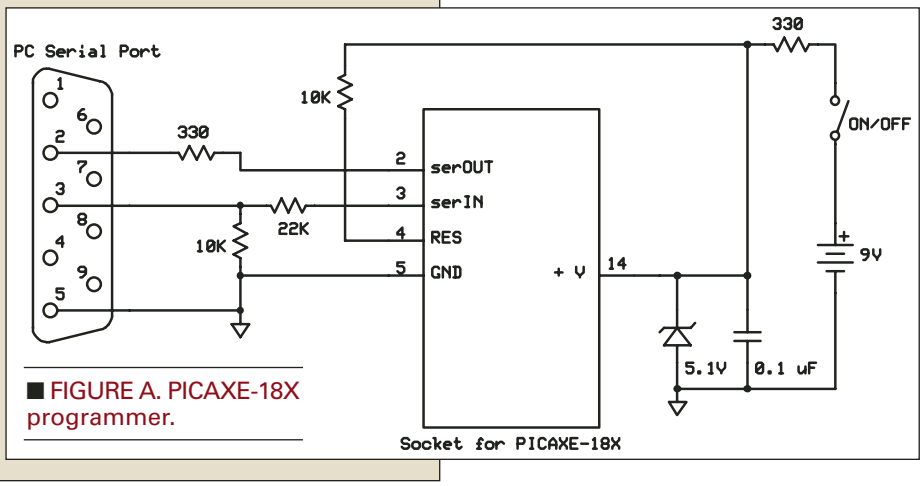
In the interest of flight stability, the board is mounted as far forward as possible in the center of the nose cone. During the rocket's boost phase, the electronics are subjected to loads in excess of 8 G. Therefore, any components that might be prone to bending leads (electrolytic capacitors, battery, etc.) are supported by silicone glue.

The next part of this article will describe the hardware and firmware required to record three channels of acceleration during flight, and then export the data to Microsoft Excel. A number of additional sensors and their application to rocketry will also be introduced. **NV**

Separate Programmer

When operating a PICAXE from a five volt supply, In-Circuit Programming (ICP) is normally performed using a simple three-wire interface to a PC serial port. Unfortunately, it is not possible to perform ICP using the flight recorder because it operates from three volts.

The PICAXE must therefore be programmed, using the separate circuit shown in Figure A, and then plugged into the flight recorder. Fortunately, this 'retro' approach to software development can be made much more convenient by using the excellent PICAXE simulator that is provided as part of its Programming Editor package.



■ FIGURE A. PICAXE-18X programmer.

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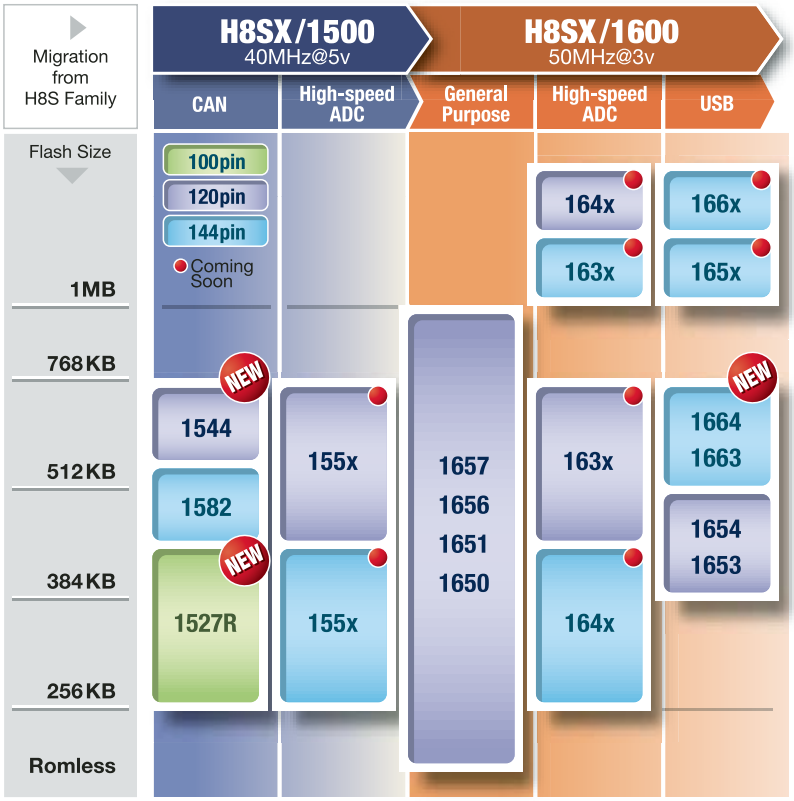

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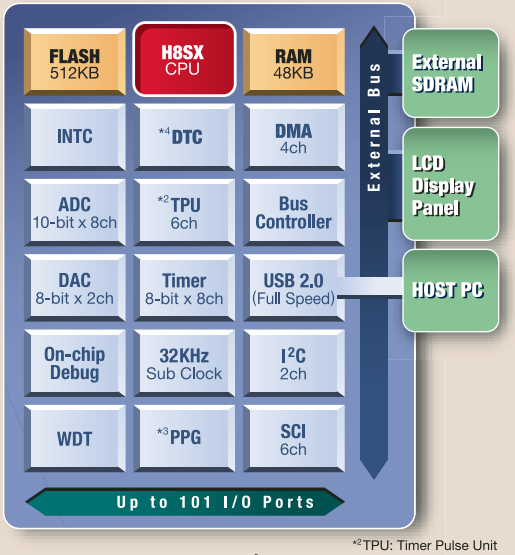

*2TPU: Timer Pulse Unit
*3PPG: Programmable Pattern Generator
*4DTC: Data Transfer Controller

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*1Source:Gartner Dataquest (April 2006) "2005 Worldwide Microcontroller Vendor Revenue" GJ06333

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THE ARBITRARY WAVEFORM GENERATOR

There are many simple sine/square/triangle wave generators available to the hobbyist. But oftentimes, something more is needed when the commonly available waves just aren't adequate. For these occasions, an arbitrary waveform generator is necessary. Unfortunately, these instruments are very expensive.

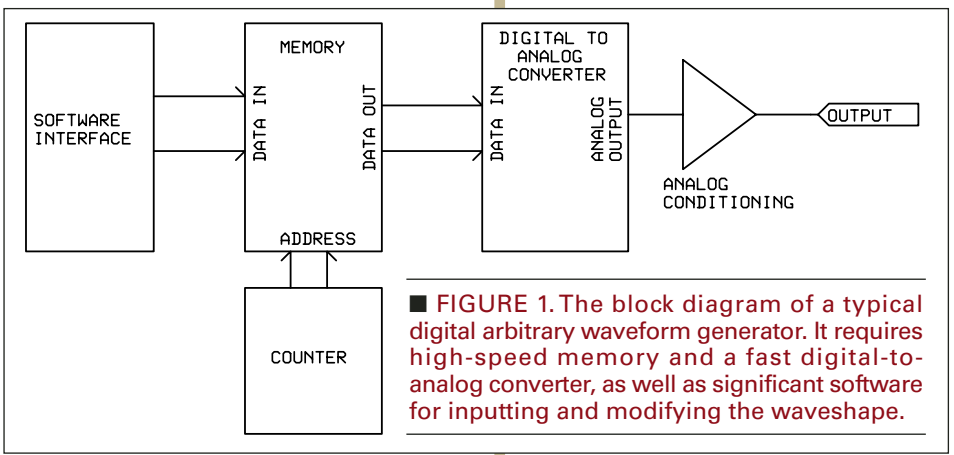
However, for about $20 you can build a basic arbitrary waveform generator (ARB) that will cover the audio range.

Digital ARB Basics

Most ARBs are computer controlled instruments that require a significant amount of hardware and software. Figure 1 shows the block diagram of a typical ARB. Basically, there is a memory circuit that holds a digitized representation of one full cycle of the desired waveform. This memory is accessed sequentially with a counter circuit to output each step in the waveform. This digital value is converted to an analog value with a digital-to-analog (D/A) converter and filtered to remove the digital edges.

There are typically several thousand steps (memory locations) possible for one cycle of the arbitrary waveform. Getting the values into the memory to begin with is not trivial and usually requires a significant software interface.

It can be seen that more waveform steps equates to a higher clock speed for a given waveform frequency. For example, a 1 kHz waveform of 1,000 steps requires a step-speed (or clock rate) of 1 MHz. A 1 kHz wave of 5,000 steps needs a 5 MHz clock. If you want to go to 1 MHz for your waves of 1,000 steps, you will need a clock rate of 1 GHz with memory and a D/A that can handle that speed. So, you can understand why traditional ARBs are expensive instruments.



■ FIGURE 1. The block diagram of a typical digital arbitrary waveform generator. It requires high-speed memory and a fast digital-to-analog converter, as well as significant software for inputting and modifying the waveshape.

Analog ARB Theory

The design presented here is an analog ARB (see Figure 2). It is far simpler than the digital ARB, so it has less capabilities than the digital ARB. However, with a basic parts cost of under $20, the price-to-performance ratio is extremely good. It is suitable for many applications where non-standard waves are needed.

The 25 step "analog memory" of the analog ARB is made up of 25 potentiometers (pots) configured as voltage dividers. Each of the 25 voltage steps of the waveform is generated by the setting of one pot. (These analog voltages eliminate the need for a D/A.) A simple digital circuit is used to sequentially select one analog voltage and present it to the output buffer and filter circuit.

There are a number of design approaches that will work to select the analog voltages in sequence. Most people would probably first think of using CMOS analog switches (CD4053

or CD4067) to do this. And this will certainly work. However, a counting circuit and miscellaneous additional logic chips are needed, as well.

I chose a different design that seemed simpler at the start (see Figure 3). Another reason for choosing this approach was because I had these chips on hand. (I initially didn't think the transistor and resistor for each step were necessary.) As built, it is arguable if the analog switch approach noted above is better or worse than the presented design. (Note that the CD4017 counters and CD4081 gates could be replaced with a simple microcontroller, if desired). The basic digital circuit consists of only five chips that typically cost under $0.40 each.

Circuit Operation

The clock signal originates from U1 that is configured as an oscillator. Six capacitors ranging from 10 pF to 1 µF are selected with a switch to control the gross frequency by a factor of 10. The fine frequency control is made with R3. Resistors R1, R2, and R3 are selected to provide a significant amount of overlap for a given range. The overall frequency range of the clock is about 10 Hz to about 2.5 MHz. This provides an output waveform from about 0.4 Hz to about 100,000 Hz with 25 steps per waveform. (Although the performance is reduced at the highest frequency setting.)

An external signal generator can be used instead if it can provide a square wave with a voltage from ground to the supply voltage. Do not apply a clock with a negative voltage or a voltage greater than the supply because that can destroy the chips. (The positive clock voltage can be about 75% of the supply and still function properly.)

The counters are CMOS CD4017 Johnson decade counters. The Johnson counter (also called a ring counter) sequentially activates one of the 10 outputs at a time. With three counters it seems that there should be 30 steps. However, this is not the case. We only want one output active at a time. But the reset state has the zero output active.

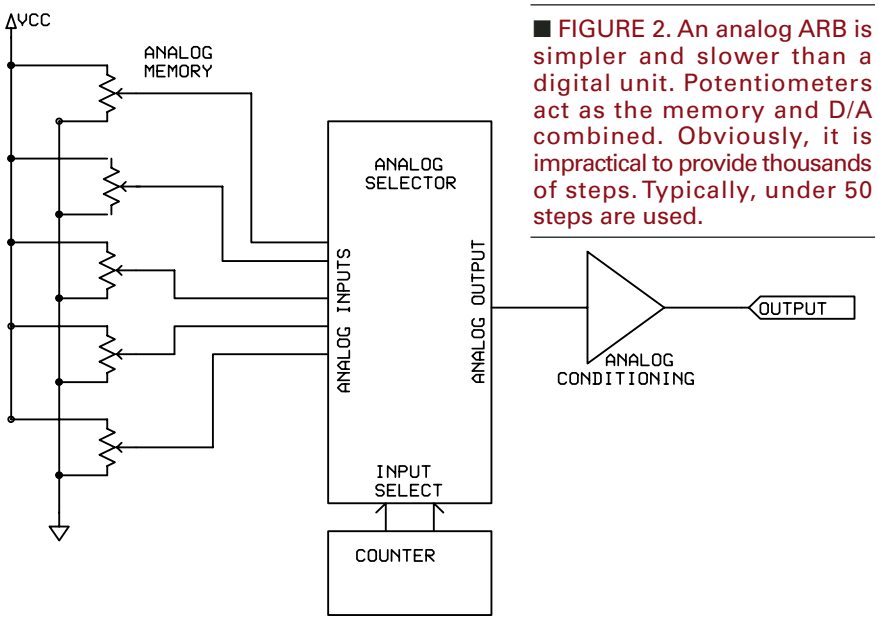
This means that the zero output for every chip except the first cannot be used. We also have to use the last count to control the activity of the counter chips themselves. So, the last count cannot be used either. Thus, there are only nine useable counts for the first chip and eight for every subsequent counter in the chain. With three counters, there are 9+8+8 or 25 counts.

The outputs of the counters go to step circuits. Initially, I thought that only an isolation diode and the variable resistor would be needed. In this way, the counters would act as analog selectors at the same time. However, this was an error and it was necessary to add the resistor and transistor to isolate the grounds. Recall that only a single output will be active (at logic high) at a time. Note that the outputs of all the step circuits are connected together.

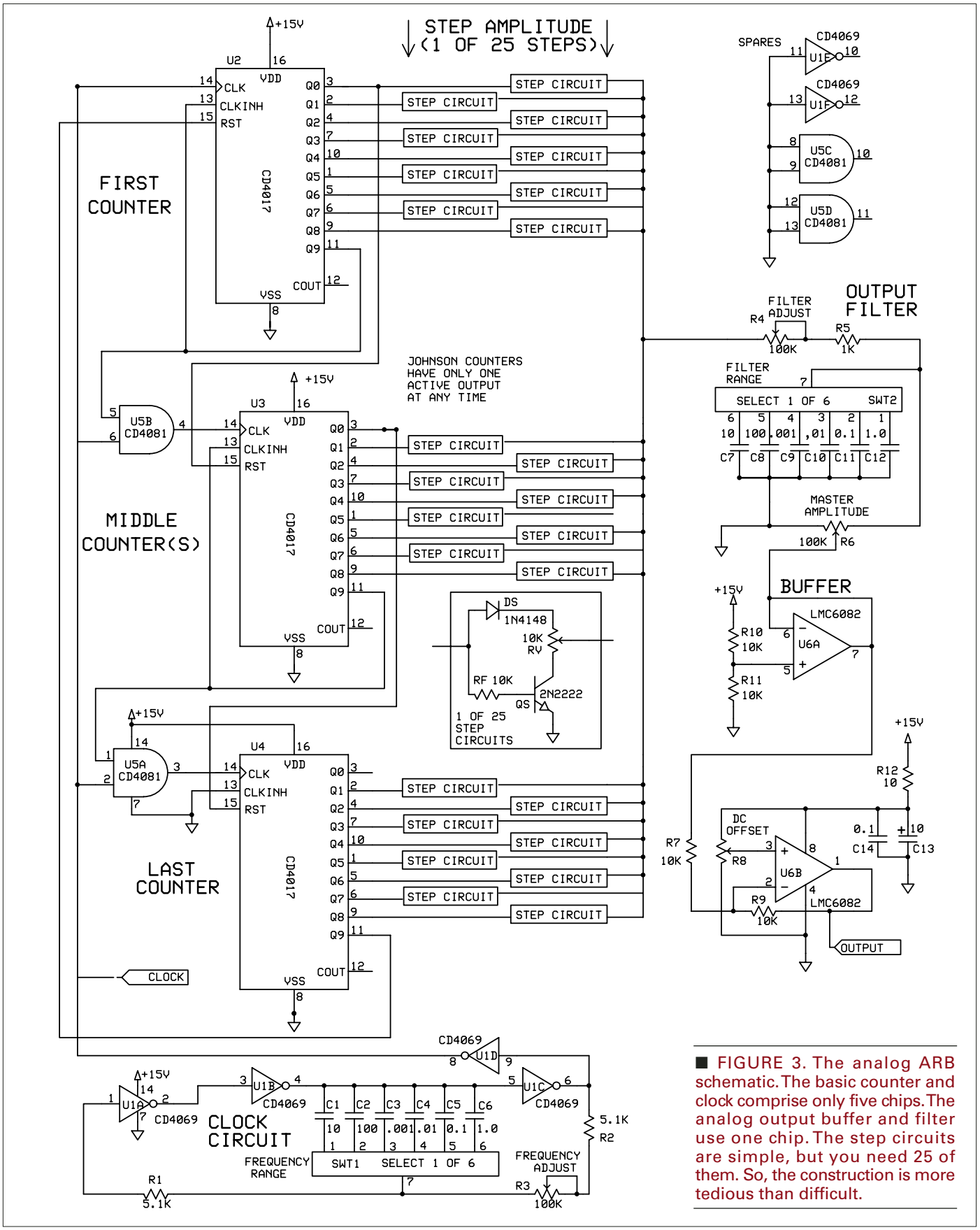
When a logic high is applied to the input, the diode conducts and applies the voltage to the top of the variable resistor. At the same time, it turns on the transistor that applies ground to the bottom of the variable resistor. The output is clearly an analog voltage from zero to logic high, depending upon the setting of the variable resistor (and neglecting any small voltage drop from the semiconductors).

When a logic low is applied, there is no voltage applied to the top of the variable resistor. It is not at logic low because the diode isolates it from the counter output. It is at a high impedance state and effectively isolated from the counter. The transistor is also turned off so that ground is also isolated from the variable resistor. The net effect of this is that the step circuit has absolutely no effect on the rest of the circuits connected to it.

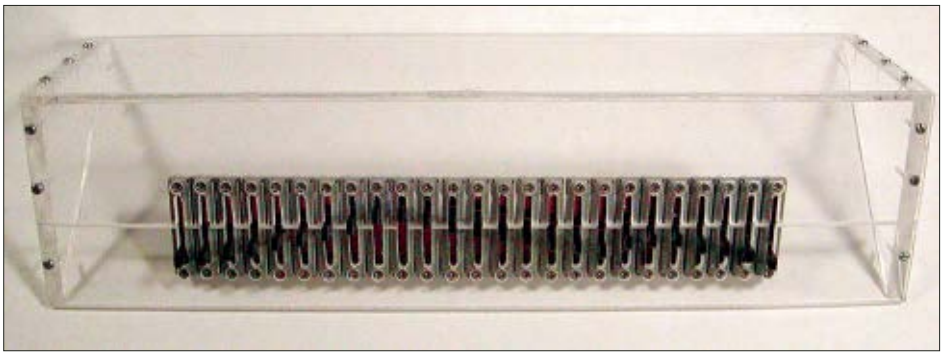
The stepped analog signal goes to a simple R-C (resistor-capacitor) filter to smooth the edges. The filter is adjustable over a very wide range and can change the waveform a little or a lot. An dual op-amp is used to buffer the output and then add a DC offset to the output. (Oftentimes there is a need for an analog signal to have a DC component to it.) The op-amp chosen is an LMC6082, dual high-speed device. It was chosen because it was on hand and met the following requirements: single supply operation, 15V operation, and high-speed (unity gain over 1 MHz).



■ FIGURE 2. An analog ARB is simpler and slower than a digital unit. Potentiometers act as the memory and D/A combined. Obviously, it is impractical to provide thousands of steps. Typically, under 50 steps are used.



■ FIGURE 3. The analog ARB schematic. The basic counter and clock comprise only five chips. The analog output buffer and filter use one chip. The step circuits are simple, but you need 25 of them. So, the construction is more tedious than difficult.



■ PHOTO 1. The hardest part of the project is mounting the 25 pots. I cut the front piece in half so I could use a band-saw to cut the slots for the controls. I made a custom triangular case from plastic. You can choose to buy or build your own case as you prefer.

Construction

Nothing is very critical or difficult about the construction. The primary concern is obtaining the slide pots at a reasonable price. I got mine at the Electronic Goldmine (**www.goldmine-elec.com**) for four for $1. The actual value is not critical and any resistance from 5K to 100K should work fine. (Note: If you get the same pots I did, you will find that you need 2 mm diameter screws to mount them. These metric screws are not usually stocked at the local hardware store but Digi-Key has them.) You don't have to use slide pots. It is possible to use ordinary rotary parts, but visualizing the waveform is much more difficult.

Mounting the pots is the most challenging part of the project. I built a triangular-shaped custom case from clear plastic (see Photo 1). I cut the face-piece in two so that I could easily use a band-saw to cut the slots for the pots. All the mounting screws hold the two pieces together tightly. Or you can simply cut out a large square section to permit the movement of the sliders, if desired.

I used two small PC breadboards for the electronics. The first board held the digital circuits (see Photo 2). The diodes are placed on end and can be seen in a row at the top. Note that this photograph was taken before I had to add the resistor/transistor switch. I mounted the additional resistors between the diodes and the counter chips. The transistors were connected directly to the pots. Photo 3 provides an overall view of the inside of the ARB. (I painted the inside of the case white.) The transistors are mounted to the pots and are difficult to see.

The analog PC board is sparsely populated as seen in Photo 4. I kept the analog circuit physically isolated from the digital board to reduce possible noise pickup. Resistor R12 and capacitors C12 and C13 also help to reduce the noise by isolating the digital and analog power lines.

The various switches and controls can be mounted to suit your preference. The final result is seen in Photo 5.

Operation

The operation is very simple especially when used in conjunction with an oscilloscope. Just adjust the Frequency controls for the frequency you need and adjust the pots for the proper waveshape. If you don't want the full voltage, you can use the Level control to reduce it. The Offset control adds a DC component to the output, if desired.

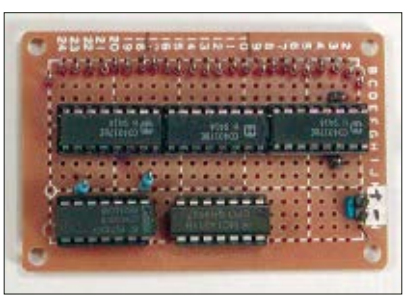
Note that it is possible to adjust the Offset control so that the wave is clipped at either VCC or ground (the amplifier obviously can't produce a signal that exceeds these limits). If you crank the Offset control all the way positive or negative, the whole waveshape will be clipped and only a flat line at ground or VCC will be output. A regulated DC supply is recommended for best operation. Typical unregulated AC adapters can introduce 60 Hz noise.

The Filter controls can eliminate the glitches at the switching points. Photo 6 illustrates a typical sawtooth wave with a deliberate negative spike placed in the middle. It is seen that there are glitches at the edges of the steps. These glitches can be removed by filtering as shown in Photo 7.

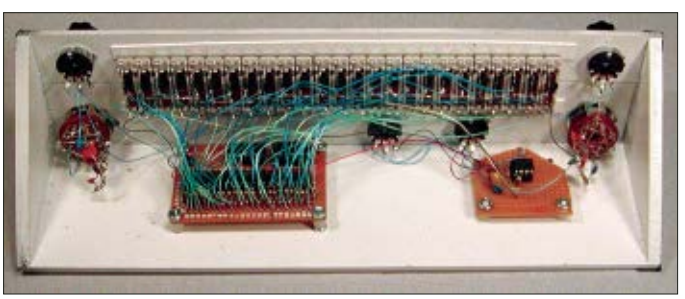
If you plan to use this without an oscilloscope, you will still have to calibrate the unit and label the settings. This will require an oscilloscope to determine the operating frequency and measure the effects of the filter.

Modifications and Going Farther

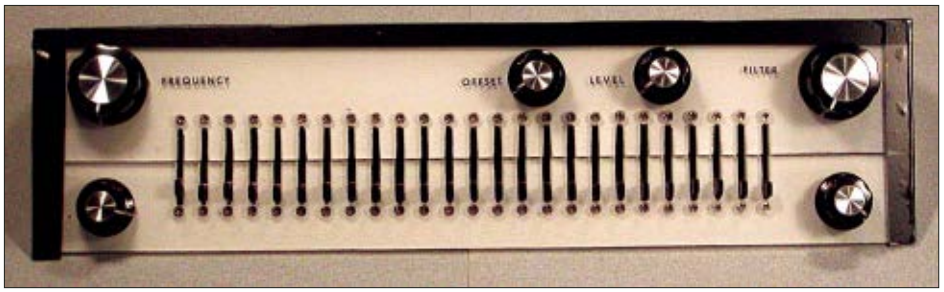
There are a number of options you can add to improve the performance. The first is to use a more



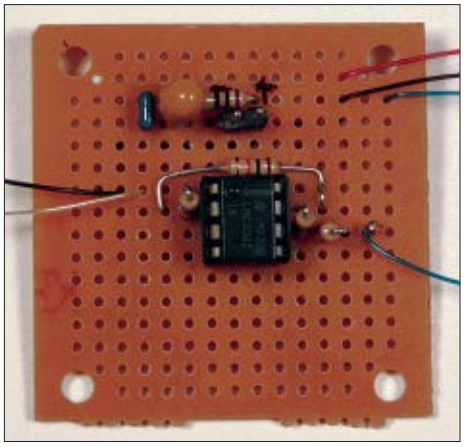
■ PHOTO 2. The digital board is not complicated. Point-to-point wiring was used. Note that the step circuit resistors are not shown (they were added later).



■ PHOTO 3. A view that shows the inside of the ARB. The transistors for the step-circuits are mounted to the pots (difficult to see). I used #30 wire-wrap wire, but any small gauge wire will work. (The inside has been painted white.)



■ PHOTO 5. The finished unit. Power and output jacks are on the back and cannot be seen.



■ PHOTO 4. The analog board is just a dual op-amp and a handful of components.

sophisticated filtering circuit. A single R-C filter is quite limited. You could cascade two or three filters in series (which would require a multi-pole switch). Adding a jack that allows an external clock to drive the system is also a useful feature, as is buffering the "Zero" output of the first counter (U2 pin 3) and using it as a sync pulse for your oscilloscope.

It is possible to build two ARBs and interconnect them so that they are phase locked. In this way, you can have a two-channel ARB (useful for stereo). The simplest way to do this is to piggy-back a second step circuit to each of the existing step circuits. These added step circuits would then be summed and go to a separate/additional analog output.

Of course, there is no need to use 25 steps. You can increase or decrease the number to suit your application.

Conclusion

An arbitrary waveform generator is a useful instrument to have. Most commercial units are expensive and have thousands of steps. The simple analog ARB described here has much less capability than a commercial unit. However, for about $20 in parts, it can provide reasonable performance in the audio range. **NV**

PARTS LIST

Resistors (1/4 watt)

❑ R1, R2	5.1K
❑ R3, R4	100K potentiometer
❑ R5	1K
❑ R6, R8	10K potentiometer
❑ R7, R9, R10, R11	10K

Capacitors (25 volts or higher, ceramic unless otherwise specified)

❑ C1, C7	10 pF
❑ C2, C8	100 pF
❑ C3, C9	0.001 µF
❑ C4, C10	0.01 µF
❑ C5, C11, C14	0.1 µF
❑ C6, C12	1.0 µF monolithic
❑ C13	10 µF tantalum

Semiconductors

❑ U1	CD4069 hex inverter
❑ U2, U3, U4	CD4017 decade Johnson counter
❑ U5	CD4081 quad AND gate
❑ U6	LMC6082 dual op-amp

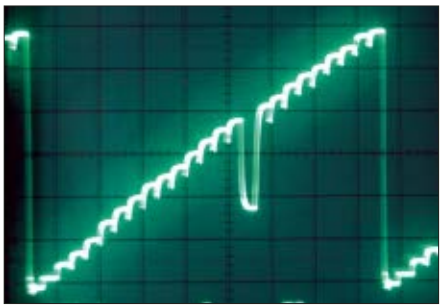
Step Circuit (One set of parts is needed for each step. As drawn, 25 of each are required.)

❑ DS	1N4148 small signal diode (or equivalent)
❑ RV	10K potentiometer (see text)
❑ RF	10K 1/4 watt
❑ QS	2N2222 transistor (or equivalent)

Miscellaneous

❑ Swt1, Swt2	One-pole, six-position rotary switch
❑ Case	
❑ Knobs	

■ PHOTO 6. A typical unfiltered output. The large glitch in the middle is deliberate the small glitches between the steps are not.



■ PHOTO 7. This is the filtered result of Photo 5. Better performance can be achieved with something more than a simple R-C filter.

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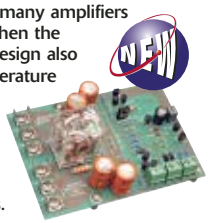

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KC-5442 Ignition System

KC5443 Coil Driver

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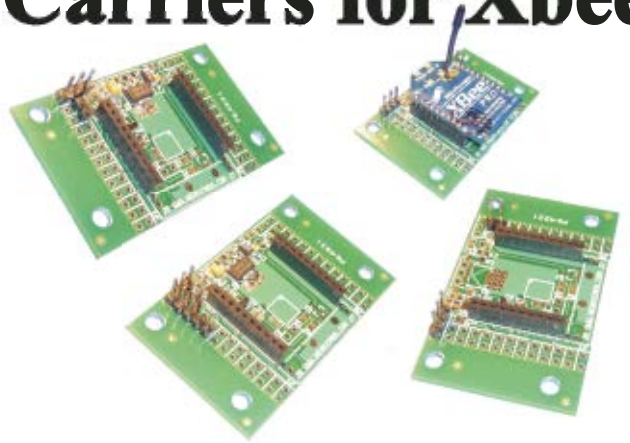

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by Isidor Buchmann

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Are Hybrid Cars Here to Stay?

Overcoming the Weak Link – the Battery

The hybrid car is not new — Ferdinand Porsche designed the series-hybrid vehicle in 1898. Called the Lohner-Porsche carriage, the hybrid function served as an electrical transmission rather than power boost. With Mr. Porsche in the driver's seat, the car broke several Austrian speed records, including the Exelberg Rally in 1901.

Another example of an early hybrid was the 1915 Woods Motor Vehicle built in Chicago. The car used a four-cylinder internal combustion engine and an electric motor. Below 15 mph (25 km/h), the electric motor propelled the vehicle; at higher speeds, the gasoline engine kicked in to take the vehicle up to a top speed of 35 mph (55 km/h). As part of the Federal Clean Car Incentive Program, Victor Wouk installed a hybrid drive train in a 1972 GM Buick Skylark but the EPA canceled the program in 1976. Meanwhile, Honda and Toyota have made strong headways by commercializing attractive and fuel-efficient hybrid cars.

The hybrid electric vehicle (HEV) conserves fuel by using an electric motor that assists the internal-combustion engine (IC) on acceleration and recovers kinetic energy during breaking. Furthermore, the IC motor turns off at stops and during slow travel. When full power is required, both the IC engine and the electric motors engage simultaneously to get maximum boost. This power-sharing scheme — the parallel-hybrid configuration — offers two advantages: it allows for the use of a smaller IC engine and improves acceleration because the electric motor has excellent torque characteristics.

Most HEVs use a mechanical drive train from the IC engine to the wheels. In this respect, the HEV is similar to an ordinary vehicle with crankshaft, clutch, and transmission, with the addition of an electric motor and a battery. Most up-and-coming plug-in HEVs use the serial configuration in which the wheels are powered by one or several electric motors. Instead of a mechanical link, the IC engine spins a generator to produce electricity for the motor(s). Similar to a laptop or a cell phone, the driver plugs the car into the AC outlet for an overnight charge. The typical driving range with a full battery charge is 20 miles or 32 km. On long trips, the IC engine engages to provide continuous power for the electric motors.

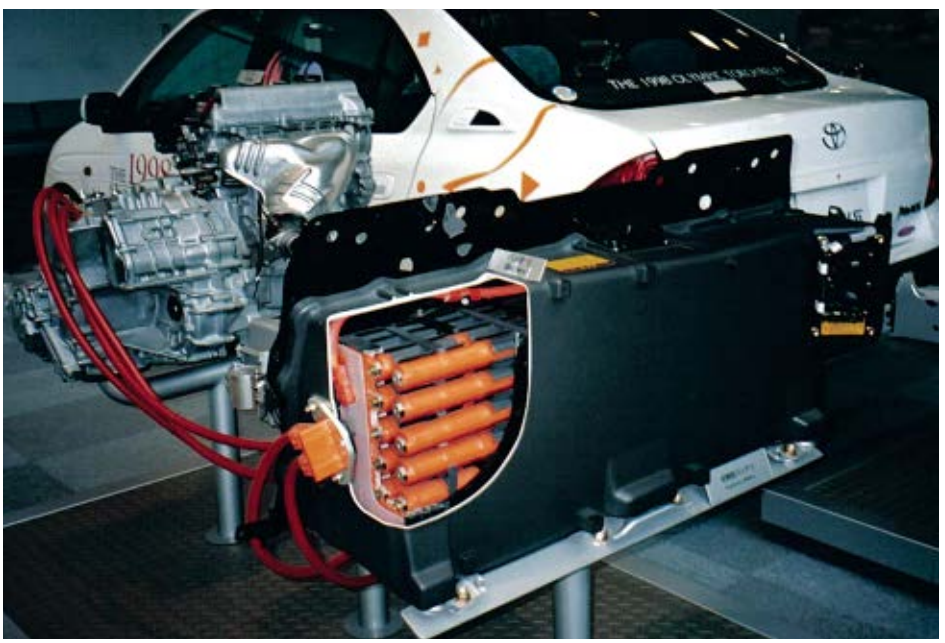


FIGURE 1. The nickel metal hydride battery of a Toyota hybrid car. The cells (orange color) are supported to allow forced air-cooling. The battery is placed behind the back seat. Photo courtesy of the Toyota Museum, Nagaya, Japan.

What's the Best Battery for the Hybrid Car?

The early HEV models used lead acid batteries because there was no alternative. Today, Honda and Toyota

employ nickel metal hydride (NiMH). This chemistry is lighter and environmentally friendlier than lead-based chemistries. The battery consists of cylindrical cells that are connected in series to attain several hundred volts. The cell strings are suspended to allow air-cooling. Figure 1 shows a demonstration pack of an early Toyota hybrid car battery.

One of the critical battery requirements for hybrid applications is longevity. Rechargeable batteries for consumer products typically last for two to three years. This short service life is no major drawback with cell phones, laptops, and digital cameras because the devices become obsolete quickly. At $2,000 to $3,000 per battery pack, the replacement cost of an HEV battery would constitute a major expense.

Most batteries for HEVs are guaranteed for eight years. To meet this long service life, the cells are optimized for longevity and not size and weight, as is the case with portable applications. Since the battery runs on wheels, the increased weight and size are not too critical.

The NiMH pack of an HEV can be charged and discharged 1,000 times if only taken to 80% depth-of-discharge. In a hybrid vehicle, a full discharge seldom occurs except if the owner lives on a mountain and requires all available battery power to commute home. Such a routine would add stress to the battery and the life would be shortened. In most other applications, the hybrid car uses only 10% of the rated battery capacity. This allows thousands of charge/discharge cycles. Batteries in satellites use a similar system in which the battery discharges less than 10% during a satellite night. NASA achieves this by over-sizing the battery.

One of the limitations of NiMH is moderate energy conversion efficiency. This translates to the battery becoming hot during charge and discharge. The charge efficiency is best at 50%-70% state-of-charge. Above 70%, the battery cannot absorb the charge well and much of the charging energy is lost in heat. Operating a battery with a partial charge requires a larger mass that lowers the energy-to-weight ratio and efficiency.

The Japanese car manufacturers have tried several battery chemistries, including going back to lead acid. Today, the focus is on lithium-ion. Cobalt-based lithium-ion is one of the first chemistries in the lithium family and offers a very high energy density. Unfortunately, this battery system cannot deliver high currents and is restricted to portable applications.

HEV manufacturers are experimenting with manganese (spinel) and phosphate versions. These lithium-ion systems offer an extremely low internal resistance, deliver high load currents, and accept rapid charge. Unlike the cobalt version, the resistance stays low throughout the life of the battery.

To verify the characteristic of manganese-based lithium-ion, a research lab applied 30,000 discharge/charge cycles over a period of seven years. Although the capacity dropped from 100% to 20%, the cell retained its low internal resistance.

The drawback of manganese and phosphate is lower energy density, but these systems provide 20% more capacity per weight than NiMH and three times more than lead acid. Figure 2 illustrates the energy densities of the lead, nickel, and lithium-ion systems. It should be noted that lithium-ion systems have the potential of higher energy densities but at the cost of lower safety and reduced cycle life.

The lithium-ion systems are promising candidates for both the HEV and plug-in HEV but require more research. Here are some of the roadblocks that need to be removed:

• *Durability.* The buyer requests a warranty of 10 years and more. Currently, the battery manufacturer for hybrid electric vehicles can only give eight years on NiMH. The longevity of lithium-ion has not yet been proven and honoring eight years will be a challenge.

• *Cost.* If the $2,000 to $3,000 replacement cost of a nickel-metal-hydride pack is prohibitive, lithium-ion will be higher. These systems are more expensive to produce than most other chemistries but have the potential for price reductions through improved manufacturing methods. NiMH has reached the low cost plateau and cannot be reduced further because of high nickel prices.

• *Safety.* Manganese and phosphate-based lithium-ion batteries are inherently safer than cobalt. Cobalt gets thermally unstable at a moderate temperature of 150°C (300°F). Manganese and phosphate cells can reach 250°C (480°F) before becoming unsafe. In spite of the increased thermal stability, the battery requires expensive protection circuits to supervise the cell voltages and limit the current in fail conditions. The safety circuit will also need to

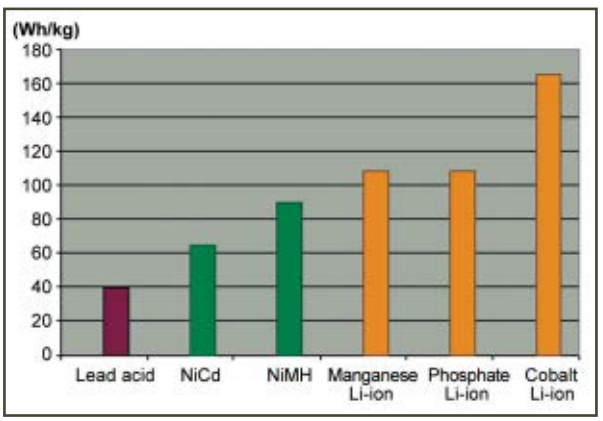


FIGURE 2. Energy densities of common battery chemistries. Lithium-cobalt enjoys the highest energy density. Manganese and phosphate systems are thermally more stable and deliver higher load currents than cobalt.

Reference

■ Menahem Anderman, *Status and Prospect of Battery Technologies for Hybrid Electric Vehicles, including Plug-in Hybrid Electric Vehicles*, January 2007.

compensate for cell mismatch that occurs naturally with age. The recent reliability problems with lithium-ion batteries in portable devices may delay entry into the HEV market.

• *Availability.* Manufacturers of manganese and phosphate cells can hardly keep up with the demand. A rapid increase of lithium for HEV batteries would put a squeeze on battery production. With 7 kg (15 lb) of lithium per battery, there is talk of raw material shortages. Most of the known supplies of lithium are in South America, Argentina, Chile, and Bolivia.

The Plug-in Hybrid Electric Vehicle (PHEV)

Imagine a plug-in electric vehicle that can go 20 miles (32 km) with a single charge from the electrical outlet at home. There is no pollution and the neighbors won't hear you coming and going because the vehicle is totally silent. With the absence of gas tax, the road system is yours to use for free. Or is it?

As good as this may sound, the savings will be small or non-existent because of the battery. Dr. Menahem Anderman, a leading expert on advanced automobile batteries, says that we still have no suitable battery for the plug-in HEV and that the reliability of lithium-ion technology for automotive applications has not yet been proven.

Unlike the ordinary HEV that operates on shallow charges and discharges, the plug-in HEV is in charge depletion mode that requires deep discharges. To obtain an acceptable driving range, the PHEV battery will need to be five times larger than the HEV battery. With an estimated life span of 1,000 full charge and discharge cycles, the battery would need to be replaced every three years. At an estimated $10,000 per battery replacement, the anticipated cost savings would be quickly exhausted.

Modern cars do more than provide transportation; they also include auxiliary devices for safety, comfort, and pleasure. The most basic of these auxiliaries are the headlights and windshield wipers. Most buyers would also want heating and air conditioning systems. These amenities are taken for granted in gasoline powered vehicles and will need to be used sparingly in a PHEV.

Analysts give another 10 years before a viable plug-in HEV will be available. The promise of a clean burning fuel cell car is still vivid in our memory. Analysts now estimate 20 years before the fuel cell is ready for mass-produced cars. There are rumors that the fuel cell may never make it into an ordinary car. If this is true, a dream will go down in history with the steam powered airplane of the mid 1800s that was simply too cumbersome to fly.

The Paradox of the Hybrid Vehicle

At the Advanced Automotive Battery Conference in Hawaii, a delegate member challenged a maker of HEVs with the claim that a German diesel car can get better fuel economy than the hybrid. The presiding speaker, being a trained salesman, flatly denied this notion. There is some truth to his claim, however. On the highway, the diesel car is indeed more fuel-efficient, but the HEV has the advantage in city driving. Power boost for fast acceleration and regenerative breaking are advantages that the German diesel does not offer.

Someone then asked, "What would happen if the HEV depletes its batteries while driving up a long mountain pass? Will the car have enough power?" The answer was that the car would make it with the IC engine alone but the maneuverability would be restrained. To compensate for this eventuality, some HEV manufacturers offer SUVs featuring a full-sized IC motor of 250 hp and an electrical motor at 150 hp; 400 hp in total. Such a vehicle would surely find buyers, especially if the government provides grant money for being 'green.' It's unfortunate that the buyers of a small car or the commuters taking public transport won't qualify for such a handout.

Conclusion

We anticipate that lithium-ion will eventually replace nickel metal hydride in hybrid electric vehicles but short service life, high manufacturing costs, and safety issues will stand in its way today. We need to remind ourselves that the automotive market can only tolerate a marginal cost increase for a new battery technology. In terms of added capacity, lithium-ion offers only a 20% increase in energy density per weight over nickel based systems. The nickel metal hydride has proven to work well in current HEVs and a new chemistry would need to offer definite advantages over present systems to find buyers.

Toyota, Honda, and Ford are leading in HEV technology. Other major automakers are expected to offer competitive models by 2010. Currently, Panasonic EV Energy and Sanyo supply over 90% of the HEV batteries. Both companies are also developing lithium-ion batteries.

While Japan and Korea are focusing on manganese systems, the USA is experimenting with phosphate, the chemistry that made the A123 Systems famous. Europe is relying on clean-burning diesel. These engines are so clean that they won't even stain a tissue that is placed on the exhaust pipe. BMW is working on a zero emission hydrogen car.

Time will tell who will be the winner in the race for cleaner, more fuel-savvy vehicles and longer-living cars. In terms of longevity, the diesel would be the winner today. We hope that future batteries will one day have the endurance to match or exceed the robust diesel engine. **NV**

by David Geer

Sun Riders Ahoy at the Solar Cup Races

Five years back, the Metropolitan Water District (MWD) of Southern California opened Diamond Valley Lake Reservoir, a fresh drinking water reservoir. To support work at the water district, clean water sports for the reservoir, and green energy and conservation, the district inaugurated the Solar Cup, a yearly event where students learn, plan, build, and race their own solar powered canoe-like contraptions.

"These kids are our future; let's get them exploring alternative energy and see where they can take it," says Water District representative, Julie Miller. But, in addition to the future of the kids, there is the future of the District with which to contend. The MWD employs many baby boomers who will eventually be retiring. "We need these kids to start thinking about a career in the water and public service areas," Miller adds.

Still, the MWD's interests are altruistic as the Solar Cup event, which includes technical workshops, education in practical math, science, physics, and engineering, and hard work teaches kids the value of these disciplines and the enjoyment of related work, not to mention teamwork. Some kids come away from these events with a new career path or even plans for college that had not crossed their minds.

While it's difficult to measure the output of such an endeavor, the Solar Cup has turned C students into college hopefuls. Some have gone on to college or a trade school and even returned to the area seeking an internship or an apprenticeship at the Water District.

Above all, the program is highly successful, giving teachers from nearby school districts the chance to excite kids about their more difficult school subjects through a fun, hands-on program like this. It's difficult when high school budgets are low to come up with an activity that the kids will latch onto and focus on for six months, notes Miller. "Not only does this teach them the text book elements like physics and science, but it also stretches them into doing team work and working under pressure," she explains.

Starter Stats, Qualifying, and Technical Stuff

Forty-three teams signed up for the 2007 Solar Cup. As the race grew and more boats and teams participated, the MWD enforced qualifying for safety's sake. Too many racers means too many people at risk.

The MWD can disqualify teams for any of a number of reasons like motor and wiring malfunctions or an overweight boat (over 451 lbs.). Using the wrong gauge of wiring can cause the wiring to fail because it can't handle the electric load for the duration of the race.

Racers are instructed to use "one sun" solar output solar panels. One sun is a measure based on the peak noon sunlight power intensity in the middle of summer, per Professor Gerald K. Herder, engineering technology department chair, California State Polytechnic University at Pomona, which supports the Solar Cup.

The teams outfit the boats with dead man switches, which are cords attached to the skippers and the boats to automatically turn the boat off if the skipper leaves the boat. The boats use spring-loaded throttles so if the skipper lets go, the engine must throttle down to zero.

Average Speeds and Other Stats

While not strictly scientific, a

Two boats racing neck-and-neck. The far boat shows deadman switch attached to skipper.

Boat with different solar panel array.

Boat with solar panels clearly visible.

Two boats leaving varying sized wakes.

measure of the average top speed of boats from recent races was taken by dividing time raced by distance covered, giving miles per hour (mph); an average of 13-14 in most cases for the top racers. One year, a boat amazed the crowds and competitors with speeds of 15-16 mph, according to Miller.

The top distance of any race has been 11 laps around a two kilometer racing area.

The Technical Workshops

The kids building and racing the boats attend technical workshops, which demonstrate how to use the hull they built to make a solar powered boat. Solar panels and electrical systems are also covered, along with the technical side of establishing good floatation, center of gravity, and anything to do with what they will add to their boats.

There is a second workshop that uses the first as a stepping stone,

AND THE SOLAR CUP WINNERS ARE ...

By May 20 2007, the Fifth Annual Solar Cup (Southern California) — the world's largest solar-powered boat race — was decided. The race matched teams of high-school students against the odds and elements.

The "veteran" category (returning competitors) winners this year were the team from Diamond Bar High School. Racers are identified as veterans or "newcomers" (first-time competitors); this year's winning newcomer team was Pamela County Park, Duarte High School.

The second and third place veteran winners were Millikan High and Canyon; Lakeside High and Rancho Cucamonga took the second and third spots overall among newcomers, respectively. Thirty-six of 41 teams won various awards in both racing and team-participation-type categories.

Diamond Bar team boat out in front in Solar Cup sprint race.

The three-day weekend racing events for speed and endurance, held at Lake Skinner, were the culmination of six months of preparation by students, team leaders, educators, and other constituents and supporters. Lake Skinner is a clean water reservoir; racers had to compete without touching water to bare skin.

During the grueling six month trial of elbow grease and education, the students learned hands-on about math, physics, engineering, boating, and boat construction while designing and building their own solar powered racing craft.

As the students prepared for the race over the course of the previous half year, they wrote four technical reports, assembled and presented visual displays on water-related issues, and generally strained to make ready for the race, as well as the future of conservation and their own futures.

Through the sponsorship of each high school's local water organizations and agencies, municipalities and governments, service-oriented groups and clubs and others, each team raised the $3,000 in fees required to learn, build, race, and have fun.

The annual event, sponsored by the Metropolitan Water District of Southern California (MWD) at Lake Skinner, points out the importance of renewable energy, resource management, and conservation. The race embodies a greater significance this year, the driest year for California, according to Tim Brick, MWD chair.

The event instills the students with sportsmanship while engrossing them in aspects of water conservation, resource management, and teamwork. Almost 900 students from five counties benefited from the

Many were in attendance at the Solar Cup races in Southern California.

And Then There's the Subject of Ingenuity!

One year, returning for the second leg of the endurance race, one skipper discovered a steering malfunction in which his boat could no longer make right turns, which is required throughout the race.

He signals back to the shore, messaging his team that he can't make right-hand turns.

Immediately, the skipper realizes that he can make complete left hand turns in order to go right, making a big circle back around in the direction he needs to go.

"Obviously, that team didn't win, but the skipper figured out how to keep participating; that's the kind of kid we want to come back and work with us at the Metropolitan Water District," noted a Water District spokesperson.

building on the original ideas with emphasis on more electronics, the motors, stability, affixing the solar panels on to the boats, and engineering a steering and drive train.

A lot of education about propellers comes into play, as these are hard for kids to figure out without a lot of help. "They don't understand that when the diameter of the propellers changes and the number of the blades change, it affects the boat," says Miller. The workshop also provides wiring examples and hands-on training for completing the wiring aspects of boat construction.

According to Professor Herder, the specific subjects covered include:

• Basic electrical theory: Ohm's law, the power law, Kirchoff's voltage and current circuit laws, series and parallel circuits, solar panel characteristics and ratings, motor control circuits, motor and motor controller characteristics,

event and the many hurdles to getting into the races this year.

By teaching the students about water conservation and resource management and by reinforcing the scarcity of and responsibility for these resources, the program prepares them to take on these responsibilities as adults; some even pursue an education or career in a related field. Through much publicity, their parents and the community learn many of these lessons, too.

The veteran trophy, which changes hands year-to-year, went to Diamond Bar High, which earned a near perfect score of 980 out of 1,000. Teams earn points for technical reports and workshops, visual displays, race qualifying, and the endurance and speed (sprint) races.

Diamond Bar has won first place two years running. The same team also won one of two endurance races (of 1.2 kilometers in distance). They also had the best veteran team technical report.

The Rookie trophy, circulated to the new winning team each year was won by Duarte High School, which also won second place in the 200-meter sprint, rookie division.

Categories in which boats and teams can place include the sprint races, endurance races, visual displays, technical reports, the Spirit of the Solar Cup, Teamwork, and Hottest Looking Boat. Awards went to Charter Oak High School of Covina (for the veteran 200-meter sprint races), Canyon Springs High School of Moreno Valley (Best Visual Display, veteran) and Lakeside High School of Lake Ellsinore (Best Rookie Visual Display).

Anaheim High School took the Bart Bezyack Spirit of Solar Cup Award (given for sportsmanship), Adolpho Camarillo High School (Camarillo) took the Teamwork Award, and Rancho Verde High School of Moreno Valley took Hottest Looking Boat (veteran). Another double winner, Arlington High School (Riverside) won both the Hottest Looking (rookie), as well as the first place (rookie) in the 200-meter sprint.

Second place also went to Canyon for veteran technical report, Damien High of La Verne for rookie technical report, and Jurupa Valley

Diamond Bar High winning team and boat; winners last year and veteran (returning competitors) winners this year.

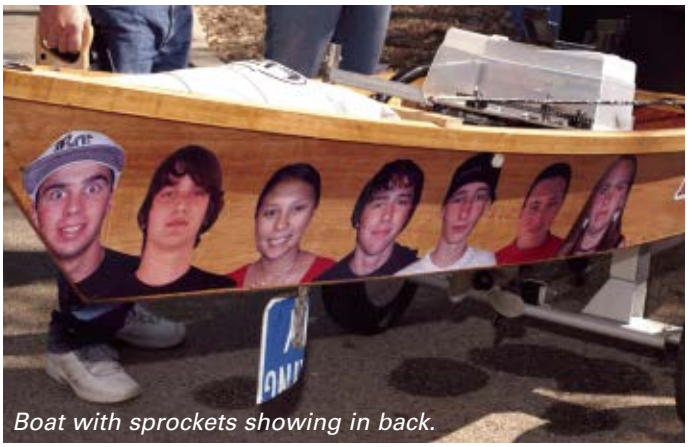
High of Mira Loma for veteran endurance race. Paloma Valley High of Menifee won rookie endurance second place.

Resources

Complete List of 2007 Solar Cup place winners, 1st, 2nd, 3rd, etc.
http://mwdh2o.com/mwdh2o/pages/education/solar_cup/2007/Sun20.pdf

Complete List of 2007 Solar Cup Awards
http://mwdh2o.com/mwdh2o/fcpages/education/solar_cup/2007/Awards.pdf

Dashboard and starting mechanism visible. Say, is this the Minnow?


Boat with sprockets showing in back.

battery characteristics and ratings.

• For the boat mechanical design: hydrostatic properties of the boat, center of gravity and stability, flotation calculations.

In the second workshop, the electrical subjects include:

• More motor and motor controller characteristics, motor efficiency, motor transmissions and gearing, typical instrumentation.

• For the boat mechanical design: motor ratings, horsepower and boat speed, displacement and planning boat hulls, propeller designs and characteristics, mechanical drive and steering systems.

How it All Adds Up

Here's how the kids learn classroom subjects from the races. For the endurance race, they have to understand the amount of power their batteries and solar panels will provide. Given that, they have to calculate how fast their boat can go over 90 minutes. The speed should be constant so as not to waste energy.

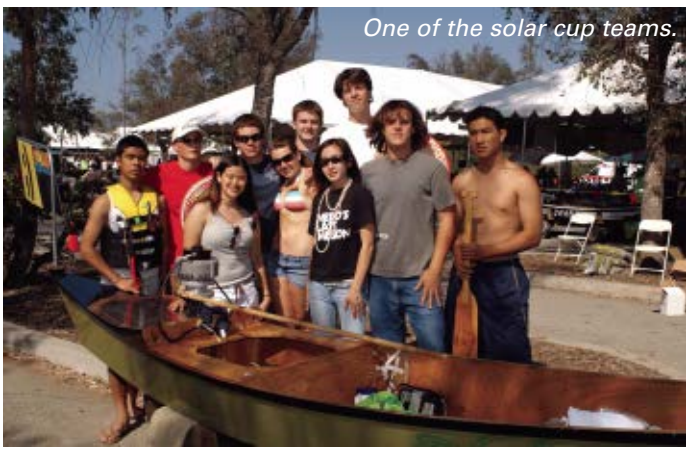
Through a lot of math and testing, they come to realize that with a certain number of amps, they can go so far in the time allotted. "When we blow the horn after 90 minutes, their boat should be dead in the water. The boat should have no energy left at all. If the boat can power back to the dock, then the team didn't have it done correctly," says Miller.

While the hulls on the boats are the same, the kids get to choose where they lay the drive shaft and its angle, how steering is engineered, and how the weight is balanced across the boat. One team member describes the experience:

"We have to maintain our weight, we have money issues, we can't spend too much, and we have to be efficient with what we get. We have to choose the right batteries, wiring, and gauges because we have to be concerned about the weight. We have to get maximum power for endurance and sprint runs."

There are limitations with wiring specs, as well. They are only allowed a certain number of watts. As for the solar cells, the teams need as much solar panel surface area visible to the sun as possible, according to another team member. Propeller selection is also important. They have to have a balance or RPMs to move with any speed. The boat also has to have the correct pitch to get optimal forward movement.

And, what have they learned? A lot of physics from the propeller engineering and the pitch. There is also a lot of chemistry covered with the electronics, in relation to voltage and electrons. The wires have a composition of certain elements; knowing those elements and their properties can help to improve the boat's efficiency. **NV**


One of the solar cup teams.

The front of the boat is up too high for the racer to see without trying to peek over. This is due to too much weight in back. A common miscalculation for new racers, according to Julie Miller of the Metropolitan Water District.

by Dan Gravatt

Two Axis Sun Tracker for Small Solar Panels

Solar panels are gaining popularity and coming down in price, but they still aren't cheap. If you have a satisfactory panel which isn't quite big enough for your application, buying a second panel for more power may represent a significant cost.

This project is designed to maximize the output from your existing panel by turning it to keep it pointing at the sun, and (hopefully) making the purchase of another panel unnecessary. The circuit can be built for much less than the cost of most solar panels.

Theory

This project works by comparing the light intensities falling on two pairs of sensors: one oriented vertically and the other horizontally. The sensors are separated by opaque dividers that will throw a shadow on one sensor in each pair if the array of sensors isn't pointing directly at the sun. If the sensor outputs are not equal, the circuit comparing the sensor outputs will move the sensors horizontally and/or vertically until the outputs are equal again.

An analog implementation of this project would be very straightforward, consisting of the sensors, an LM339 quad comparator, and two H-bridges to drive DC motors. I did build a one axis sun tracker in this manner just to evaluate different sensors, and to illustrate the major drawback of analog comparators for this application: the lack of hysteresis.

The comparators will always drive the motor one way or the other, leading to a continuous "jitter" when the sensors are pointed at the sun. Thus, to be practical, the circuit must compare the sensor outputs and then determine if the difference is large enough to require moving the sensors.

Sensor Selection

I had hoped to use phototransistors as the sensors for this project, and got good results with them using a flashlight in a dark room. However, the phototransistors were completely overloaded or saturated in direct sunlight. Similar results were obtained using LEDs as light sensors. Miniature photovoltaic cells would have worked, but the added cost was more than I had hoped. This left one inexpensive option: cadmium-sulfide photoresistors.

These work very well in direct sunlight when used in series with another resistor to form a voltage divider (Figure 1). Each pair of photoresistors must be well matched to provide identical resistance at a given light intensity.

Circuit Design

The circuit is based on a Microchip PIC16F876A microcontroller which includes (among other things) a five-channel, 10-bit analog-to-digital (A-to-D) converter which we can use to "read" the photoresistors. While this chip has far more features and horsepower than the circuit requires, it does have two distinct advantages for the low-budget builder: it is supported by the free trial version of microEngineering Labs' PICBasic Pro compiler; and you may be able to get free engineering samples from Microchip. The overall schematic is shown in Figure 2.

The four photoresistor voltage dividers are connected to the first four channels (RA0-RA3) of the PIC's A-to-D converter in the order shown. Outputs RB0 and RB1 send pulse width modulated (PWM) signals to the vertical axis and horizontal axis servos to move the solar panel. For simplicity's sake, if your solar panel is very small, you may be able to power the servos from the same five-volt supply which powers the PIC. If your servos need more torque or if you suspect the motors are causing supply voltage dips which affect the circuit operation, it's best to use separate regulators as shown.

How it Works

The program code (available on the *Nuts & Volts* website at **www.nutsvolts.com**) starts out with a loop to sample the analog output from each photoresistor voltage divider, convert it into a 10-bit value, and store it in a four-word array variable. Next, the values from the top and bottom sensors are compared to

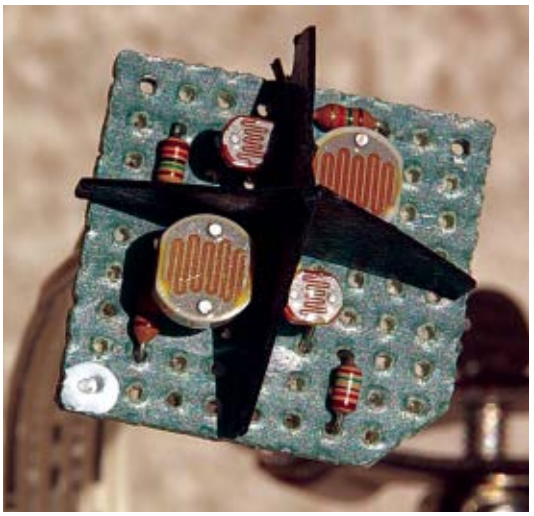
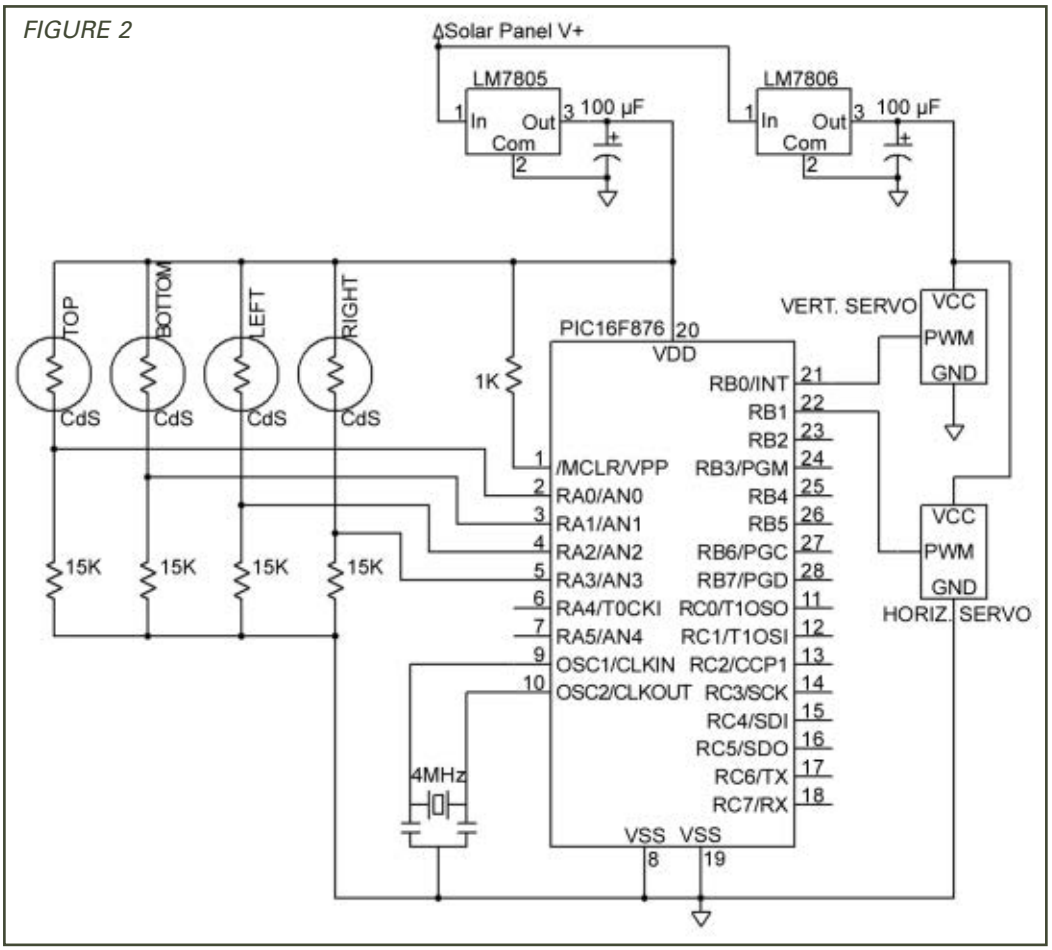


FIGURE 1. Close-up of sensor array with opaque dividers.

FIGURE 2



determine if they differ enough to require a movement of the solar panel, and the left and right values are also compared.

This comparison provides the hysteresis function that is missing from the simple analog implementation described above.

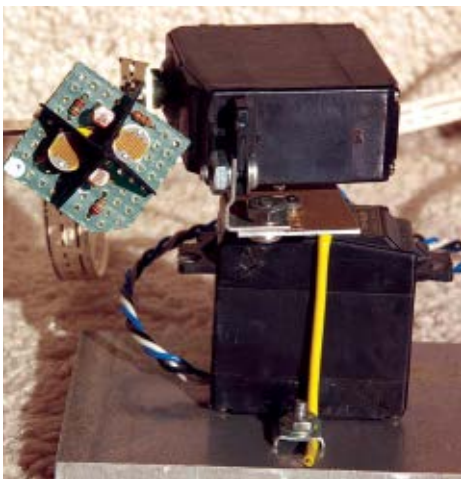
If the difference between either set of values requires a movement in either axis, the direction of the required movement is determined, and then the output pulse width to each servo is adjusted accordingly. The code then loops back to resample the sensors and repeats the comparison and adjustment process indefinitely.

This code barely fits within the code length limit of the free trial version of the PICBasic Pro compiler, and therefore the method for comparing the sensor outputs and determining what adjustments are required had to be extremely simple. Because of this simplicity, there is the potential for positioning errors to occur if the sensors end up pointing too far from the sun (such as at sunrise, when the sensors are still pointing towards last night's sunset).

This limitation in the code may make it unsuitable for a permanent, unattended solar panel installation. This is not a limitation of the hardware, and more sophisticated code compiled with the full-function version of the PICBasic Pro compiler can easily get around this issue.

Finally, keep in mind that this code must be compiled with the PICBasic Pro compiler, since the ADCIN instruction used to perform the A-to-D conversion is only implemented in that version of the compiler.

FIGURE 3. Sensor array mounted on servos for testing purposes.



Parts List

- SPIC16F876A microcontroller
- 4 MHz ceramic resonator with capacitors
- 7805 five-volt linear regulator with heatsink
- 7806 six-volt linear regulator with heatsink
- (2) Hobby servos, sized appropriately for the solar panel you will be using
- (4) Cadmium-sulfide photoresistors, matched in pairs
- (2) 100 µF capacitors
- (4) 15K ohm resistors, 1% tolerance
- 1K ohm resistor

Construction

The mechanical construction of the sensor array is more important than its electrical construction, and will in large part determine how well the sun tracker works. The four photoresistors should be mounted as closely as possible to each other, spaced equally in a square grid pattern. The faces of all four sensors should be in the same plane. The opaque dividers between the sensors should extend far enough in front of the sensors so that a minor movement of the sun will begin to shade one of the sensors and cause the array to move. Once your sensor array is

finished, mount it on the edge of your solar panel, keeping the faces of the sensors in the same plane as the panel.

Figure 3 shows my prototype sun tracker in testing, illustrating how one servo was mounted on the other to move the sensor array in two axes. I recommend testing your sensor array's behavior in this way prior to building your solar panel mount, as it will be much easier to correct any problems at this stage. Note that it is not necessary for all four photosensors to be matched; only the two in each pair need to have their outputs match.

I won't go into great detail on the construction of the solar panel mount and servo adjustment linkages because everyone's setup will be different. I plan to mount my panel on a post at the panel's center of gravity, with a horizontal rotary bearing and a hinge between the post and the panel to allow two axes of movement. One servo will mount on the fixed post just below the bearing to turn the panel horizontally, and the other servo will mount on the back of the panel to move the hinge joint vertically.

If your solar panel is fairly large or heavy, servos will be too weak to reliably position the panel. In that case, the portions of the code which adjust pulse widths can easily be modified to control an H-bridge and drive DC gearmotors of whatever size your panel requires.

Fine-tuning

After your circuit is complete and the PIC is programmed, test its behavior to make sure you have wired everything properly. If the array turns away from the sun in either axis, or otherwise acts strangely, check that the sensors are connected to the proper A-to-D converter channels and that you haven't reversed the servo outputs.

You may also need to fine-tune the hysteresis value in the code to match your particular sensors. I found that the behavior of the circuit indoors is very different from its behavior in full sunlight, so test your sensors outside!

The code as written won't move the solar panel unless the digitized sensor values in either pair disagree by more than ±10. Increase this value if you observe "jitter" in the servos when pointed at the sun. If you find that the sun moves a long way across the sky before the sensors react, the dividers between your sensors may need to be adjusted, or your sensor pairs may not be matched well enough.

Now you're ready to get maximum power output from your solar panel all day! **NV**

Contact the Author

■ *Dan Gravatt is a licensed geologist in the state of Kansas. He can be reached at dgravatt@juno.com.*

by Dick Aidt

Build a Solar Thermal Water Heater Controller

The weather in my part of Florida on the Space Coast is usually very nice in the winter. That being said, it is not unusual for the temperature to get into the mid 30's on an occasional winter night. It was one of those rare instances that prompted me to create this project.

My solar collector is a good heat absorber, and unfortunately, equally good at radiating that same heat back out to the sky. This means the collector can drop below ambient temperature during cool clear nights. On one such night, the water in the collector froze and the pipes burst. My old solar controller failed to perform its job, which is to pump hot water from the tank in the utility room into the collector on the roof for freeze protection — the circuit had apparently become unreliable. Thus my plan to build another controller!

Collector Basics

The collector is made up of copper tubing and copper flashing sheets, assembled in an aluminum box with a glass cover. Its dimensions are 10 feet by four feet and about three inches thick. To start this project, I installed LM35DT sensors at the inlet and outlet of the collector. I also opened an access hole at the exact center of the collector and installed another sensor there.

A neat way to mount the LM35DT (which is available in a TO-220 package) is to solder a 6-32 flat head brass screw directly onto copper pipe to be sensed. I used brass nuts and thermal compound to complete that installation.

The pump for the system draws about 100 watts while running, which is a lot better than the 1,500 watts used for the heating element. I found that with my system, this heating element operates after about two days of no sun. Its thermostat is set at 120°F on the element, however, it only takes about two hours of full sun to get up to this temperature, and even in mid winter, water temperature is usually far above that.

The typical temperature is somewhere above 160°F in winter and higher for summer. With the original installation, the pressure/temp relief valve (195°F) at the collector top would occasionally pop off, therefore during collector repairs, I installed a high temperature version (210°F). This lets you know what kind of temperatures can be expected in the summer around here (if you're a copper heat absorber).

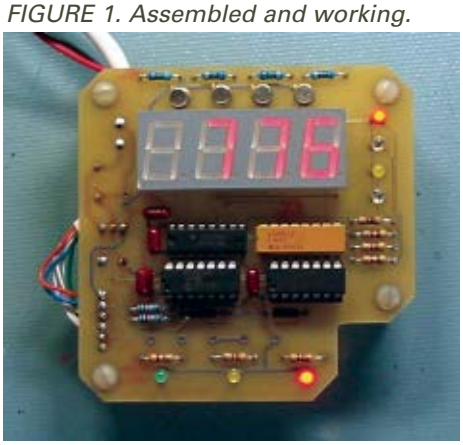
The hot water tank is the "standard solar water heater" which has four pipes of different lengths fed into the top of the tank housing. The house feed line takes hot water from the top of the tank, and the water feed into the tank goes approximately half way down into the tank. The water to the collector is pumped from about six inches above the bottom and the collector output is inserted about 18 inches from the bottom. The hot water migrates to the top of the tank through the convection process.

These tanks are available from most solar utility companies here in Florida. They can also be obtained on-line or through special order from a plumbing supply company. My tank is about five feet high, with a 24 inch diameter and holds 80 gallons. A thermal sensor is mounted on the exterior surface at the bottom of the tank. The output of this sensor is included in my code as the variable "Tbot."

Design Approach

The old controller is one of those old-fashioned transistorized versions that has a slide switch that was constantly getting dust contamination. It uses a transistor flip flop clock and several other transistors for relay control. It also has an advanced 741 op-amp used as a comparator and some 4066 DIP solid-state switches. I decided to use a programmable device rather than go

FIGURE 1. Assembled and working.



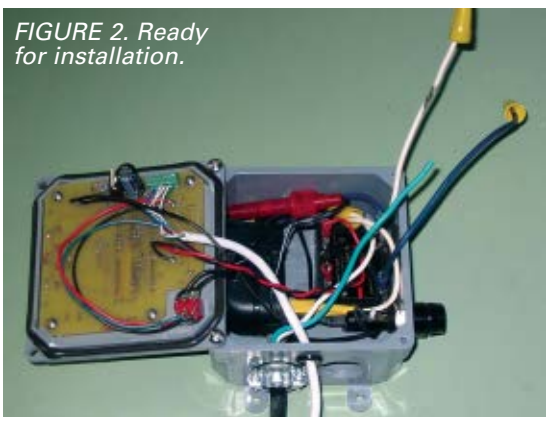


FIGURE 2. Ready for installation.

through the component selection routine required to match the design of the original controller. I wanted to eliminate the mechanical relay, open slide switch, and nonlinear thermistors, as well. I needed something in a small package and finally settled on the 14 pin DIP PIC16F684. This chip was selected because it has eight A/D channels with 10 bit resolution, which will work well with the LM35DT linear temperature sensors.

Circuit Design

My original idea was to make a controller for the pump only, but I later added the digital readout for the temperatures. This is the reason my design uses two of the PIC16F684 packages. The schematic and printed circuit board (PCB) were designed using software from ExpressPCB (see Resources). I found their design software very easy to use, but note that you should do a line by line check of your design, as there are no error detecting features to check your layout for mistakes.

Your PCB data created in their software is uploaded to them and the order is placed for the boards (the PCB files, as well as the code listing, are available on the *Nuts & Volts* website at **www.nutsvolts.com**).

Board assembly is fairly easy due to the DIP devices and through-hole components. No SMDs are used. The components in the regulator circuit (Q5, C1, C2, and C3) are placed on the bottom side of the board to allow the board to be mounted a 1/4 inch from the surface of the box's front cover. TB1 is also mounted on the bottom for better access to its terminals. See Figures 1 and 2 for photos.

Schematic Details

Each LM35DT sensor has the 5V supply decoupled with 0.1 µF capacitors and a 1.0 µF capacitor in series with a 10 ohm resistor to account for capacitive effects of long wire runs. The compensation is probably not needed in my case, as the wire runs are only about 30 feet long.

Each sensor output is fed to an A/D channel on the first PIC16F684 (U1). There, the signals are converted to digital data, using 2.5V as a reference. The reference voltage is derived from the R14 and R15 voltage divider on the 5V supply. The digital data are compared in software to make the

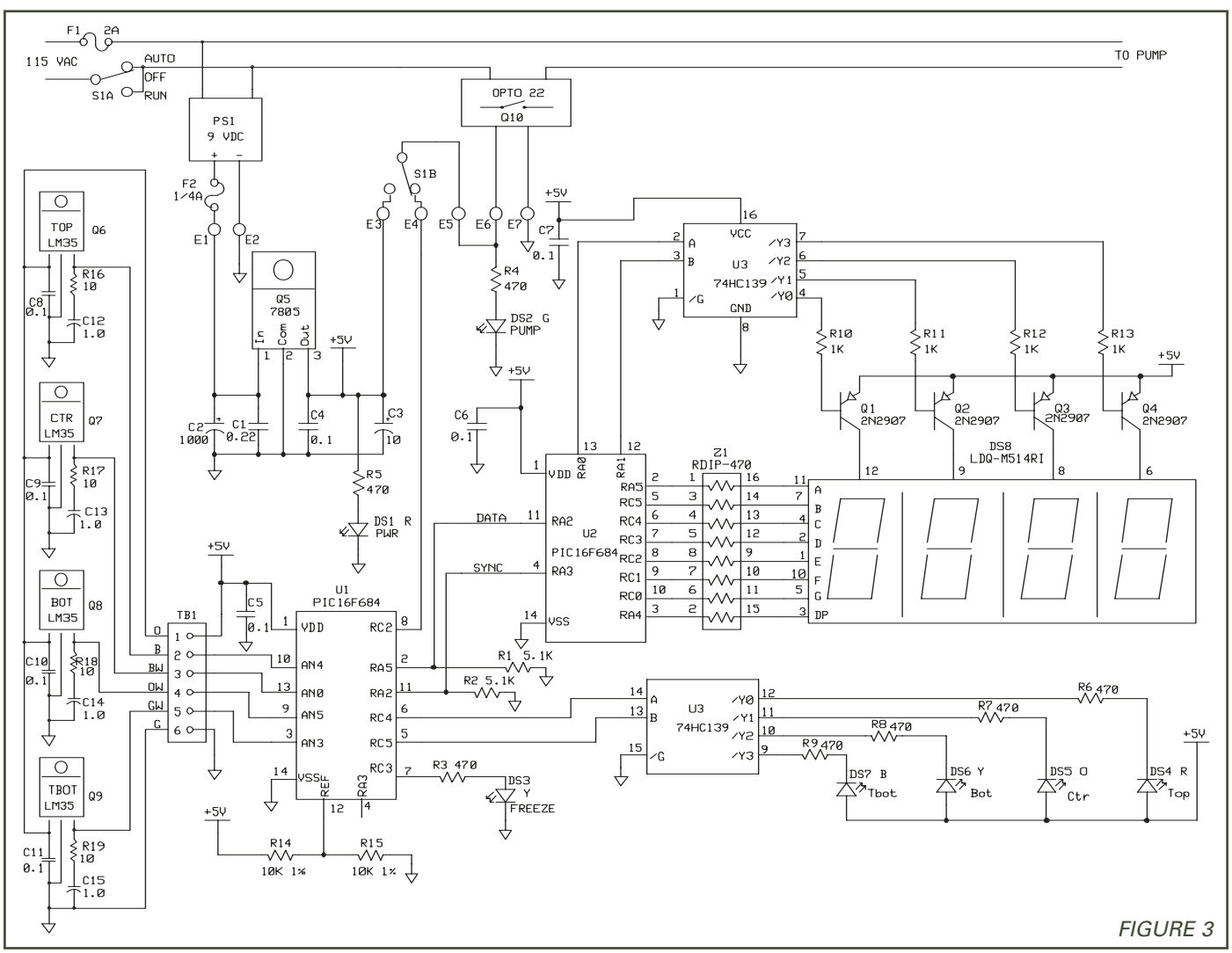


FIGURE 3

FIGURE 4. The finished project.

decision of "pump on" or "pump off."

The pump is controlled from port RC2 by sending a signal to the solid-state relay (U10) and to a pump running an LED (DS2) to indicate status. Another LED (DS3) is controlled by port RC3 to indicate if the pump is running because of freeze protection.

Other tasks performed include sending each temperature reading to the second PIC16F684 (U2) for display, and clocking decoder (U3) for the purpose of turning on LEDs that indicate which temperature is being displayed. The data received by U2 controls the quad seven segment display. Half of the U3 decoder is also used in this process, along with associated display driver transistors.

The power supply consists of a 9V wall block regulated to 5V using a LM7805 regulator. A fairly heavy filter capacitor (C2) is 1,000 µF which guards against major voltage drops, allowing the system to work properly during the switching of S1 from pump "automatic" to "run" mode. See Figure 3 for the schematic.

Resources

- *All Electronics* — **allelectronics.com**
- *RadioShack* — **radioshack.com**
- *Home Depot* — **homedepot.com**
- *Microchip* — **microchip.com**
- *Hi-Tech Software* — **htsoft.com**
- *ExpressPCB* — **expresspcb.com**
- *Digi-Key* — **digikey.com**

Parts List

ITEM	DESCRIPTION	PART NO./SUPPLIER
C1	.22 µF 250V	ECQ-E2224KB/Panasonic
C2	1,000 µF 25V	UVR1E102MPD/Nichicon
C3	10.0 µF 50V	UVR1C100MDD/Nichicon
C4-C11	0.1 µF 50V	ECQ-V1H104JL/Panasonic
C12-15	1.0 µF 63V	2222 021 38108/BC Components
DS1, DS5	Red LED	SSL-LX3044LID/Lumex
DS2	Green LED	SSL-LX3044GD/Lumex
DS3, DS6	Yellow LED	SSL-LX3044TD/Lumex
DS5	Orange LED	SSL-LX3044SOC/Lumex
DS7	Blue LED	SSL-LX3044USBD/Lumex
DS8	Quad seven seg	LDQ-M514RI/Lumex
F1,2	Fuse holders	1/4 A and 2 A/RadioShack
PS1	115 VAC to 9 VDC	RadioShack
Q1-4	PNP Transistor	2N2907/STMicroelectronics
Q5	5V Regulator	LM7805CT/Fairchild
Q6-9	Temp sensor	LM35DT/NOPB/National Semi
Q10	Opto Relay	SRLY-18 /All Electronics
R1-2	5.11K 1/4 W	MFR-25FBF-5K11/Yageo
R3-9	475 ohm 1/4 W	MFR-25FBF-475R/Yageo
R10-13	1.0K 1/4 W	MFR-25FBF-1K00/Yageo
R14-15	10.0K 1/4 W	MFR-25FBF-10K0/Yageo
R16-19	10 ohm 1/4 W	MFR-25FBF-10R0/Yageo
S1	DPDT ctr off	100DP3T1B1M1QEH/E-Switch
TB1	Six Pos term	1725698/Phoenix Contact
U1,2	PIC16F684	Microchip
U3	Dual 2 to 4 DEC	SN74HC139N/Texas Inst
Z1	RDIP-470	4116R-1-471LF/Bourns, Inc.

Software and Testing

I used Microchip's MPLAB IDE along with the PICC compiler from Hi-Tech for writing the software. One advantage of the MPLAB utility is its ability to perform simulations on the code. I made many iterations from the editor to the compiler to the simulator before creating something that worked as I wanted. For programming the PIC, I used the Microchip PICStart Plus unit. Be aware that the PICStart requires an RS-232 port, and some laptops (such as mine) have only one on its associated docking block.

There are two program listings used here, one for each of the PIC16F684s. The real controlling happens in "Thermal.c," code for (U1). That's where the pump on/off decisions are made. This program will turn the pump on when the collector's top outlet has a temperature greater than five degrees above the bottom of the hot water tank, and runs the pump until the top temperature is only two degrees above the tank bottom.

For freeze protection, it will turn the pump on when the center of the collector drops to 37 degrees, and runs it until the center temperature is greater than 42 degrees. It indeed works, because I stood there and watched it on one of our cool February nights. I was surprised that it only takes one or two minutes of pump on time to satisfy the unit for protection.

The original system only sensed the top and bottom of the collector, but my reasoning told me the center of the collector should be the most temperature variable part of the collector. The first installation of the new system has shown this to be true, so I modified the software to sense the center temperature for freeze protection.

The "Thermal.c" code also converts each of the sensor readings from Celsius to Fahrenheit, then produces a data stream of each reading that is

sent to the "Display.c" code for (U2). "Display.c" takes the temperature data and displays it on the quad seven segment LED display. Four LEDS of different colors indicate which temperature is being displayed. The three other LEDS indicate an "active pump," "power", and "pump running for freeze protection." Again, all program listings are available from the *Nuts & Volts* website.

Hardware Packaging

In order to have a controller that could be easily installed, I opted for a PVC junction box from a local home improvement store. See Figure 2 for the large component placement. The 9V power block was modified slightly by soldering wires to the AC prongs and using shrink tubing. The block is then bonded into the box using RTV rubber cement (GOOP). The solid-state relay is fastened to the box bottom with 6-32 hardware. The fuse holder F1 is mounted in the box and F2 is on pig tails and stuffed into the box.

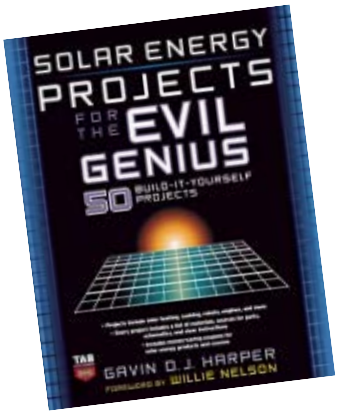
Use care when installing the front panel with the PCB attached, as there is not much clearance left. The box is only a 4" x 4" x 2" and, in hindsight, a 5" x 5" board would have been easier. The fuse holders and power block (PS1) are from RadioShack. All the other components are from Digi-Key. The solid-state relay (Q10) is from All Electronics.

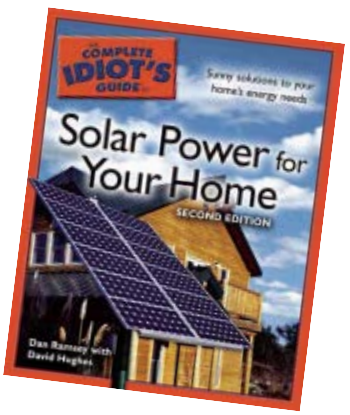
Future Improvements

For the future, I would like to add a data logger that will put the temperature readings onto a Flash drive. Then I could load the data into Excel and make a chart of the results. Currently, I am reading these data manually with four hour readings and a clip board. I'm looking to use the PIC16F877 for this upgrade, but not sure something that powerful is required.

Maybe I can think of something else for it to do, like monitor solar intensity for calculations on a photovoltaic system to run the pump. That way, I will have totally free hot water. **NV**

For more information on this exciting subject, see our section in the book store on Page 97 or the website on GREEN POWER.





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by Dan Casale

An Introduction To Solar Electric For Your House

I'm so bright, I generate my own electricity ... I need a T-shirt and a bumper sticker with that saying! I was designing a base and space station power generation system for a moon/Mars colony group (**www.1000planets.com**), when a co-worker asked me to help design a stand-alone solar power (PV) system for an off-grid home she was planning to build.

As we worked through the design, I kept thinking, I need one of these. The year was 2003, gas was at the ridiculously high price of $1.50/gallon, I had just purchased a "you must be crazy to buy that thing" Prius and California was doing a very innovative thing — energy deregulation.

Like any good project, the more research I did the more options became apparent, and the more the project cost. But here's how I built my system.

Energy Storage

While this might seem like the last thing to decide, it will affect how the whole system is designed. Luckily for the homeowner, there are only two real options and one "fringe" option.

• **Storage Option #1:** Most homes are already connected to the local utility grid, so the easiest storage method is simply to spin the electric meter backwards. This option is often referred to as "net-metering." Not all utilities have a net-metering provision, so this might be the first factor limiting the size of your future system. I say this because if you put on a large system and your power bill is negative, you will quickly have the full undivided attention of the utility company. Smaller "unauthorized" systems are often referred to as "Gorilla Solar" systems.

• **Storage Option #2:** Batteries. If you have decided that being attached to the local utility is not for you, or you want a whole house UPS, then batteries are in your future.

• **Storage Option #3:** Hydrogen. Be the first person on your block to invest in the hydrogen economy.

Energy Collection

Solar panels require a large, south facing area that is free from shadows. Figure about 100 square feet for each 1,000 watts of peak power production. Additionally, the panels should be tilted at an angle equal to your latitude for best year-round performance.

The roof is generally a winning location. However, most roofs are not steep enough for optimum power production, so some type of tilt-up racking may be necessary. The available area is likely to be the second limiting factor on the size of your future PV system.

There are two basic types of mounting systems: fixed orientation or tracking. Each of these types has two options. For the fixed orientation, the options are fixed or seasonally adjustable. Seasonally adjustable racks are used to change the panel angle to optimize winter and summer performance.

The two types of tracking systems are single axis and dual axis. Single axis systems will track the sun across the sky while dual axis systems track the sun across the seasons. Trackers follow the sun like flowers and can increase a system's output by

Winter angle.

Summer angle.

Fuse box wiring.

Inverters.

more than 20%. This is ideal for someone with limited space.

On the downside, a windy day will cause the panels to "feather" by laying flat. Also, any moving part will eventually require maintenance and, as panels have a 40 to 50 year life expectancy, at least one replacement should be factored into the system life cycle costs. Tracking systems generally use top-of-pole mounting and require a monolithic footing for structural integrity.

Sizing the PV System

For a grid attached home, add the last 12 month's consumption from utility bills and divide by 365. This is your average daily consumption.

Next, consult **http://rredc.nrel.gov/solar/pubs/redbook/** and find the group of readings that match the type of system you plan to install (fixed, single axis, dual axis). On the line that indicates the correct tilt angle, read across to the year column for the average and min/max readings. This is the average number of hours of full sun available each day.

If you are evaluating trackers, use these figures to evaluate the effectiveness of a single or dual axis tracker by dividing those numbers by the fixed panel number. In my case, I live in an above average area with 5.8 hours of full sun per day. A single axis tracker would increase that amount by 36% to 7.9 hours, and a dual axis tracker by 41% to 8.2 hours.

The size of the PV system is:

<Daily Consumption (kWH)> / <Hours of full sun> = <Size in kW>

In my case, 20 kWH / 5.8 = 3.448

At this point, begin searching for system kits on the Internet. Generally, a kit will include panels, one or more inverters, an AC disconnect, and a DC disconnect. Sometimes the disconnects will be bundled inside the inverter or mounted together on a board, and will generally be called a power panel. The easiest way to compare systems is by using COST/WATTS. Be sure to check for UL listings and NEC compliance.

Derating the System

The system must now be derated for panel temperature, inverter inefficiencies, and wiring losses. Panels are rated by the manufacturer using the STC method. STC stands for Standard Test Conditions of 1,000 watts per square meter, 70°F panel temperature, and no wind. Additionally, a temperature performance curve is developed for each size of panels and this becomes very important for cold weather performance.

Because of complaints that panels were not performing as expected, California developed the PTC rating. The amount of light is the same

Definitions

- *PV* — Photovoltaic
- *HOA* — Home Owner's Association
- *Grid-Tied* — A house attached to the utility grid
- *Stand-alone* or *Off-Grid* — House not attached to the utility grid
- *Panel* — A collection of solar cells group together with one positive and one negative lead
- *Array* — A collection of PV panels in series
- *Charge Controller* — A device that uses power from a solar array to charge batteries
- *Inverter* — A device for converting DC to AC
- *System* — One or more inverters with one or more arrays attached
- *NEC* — National Electric Code
- *UL* — Underwriter's Laboratories
- *PTC* — Practical Test Conditions, California testing standard
- *STC* — Standard Test Conditions,used by manufacturers to rate panels

System Economics

Item	Cost
Initial cost	$52,689
Green energy credits sold	-25,000
Tax credits & deductions (over 5 yrs.)	-16,000
Total Cost	$11,689
Payback Period (Yrs.)	7.2
Annual Electricity Savings	$1,519
Annual Gas Savings (Electric Heating)	$105

Pipe trench.

(1,000/Watts/Meter^2), however, the temperature was increased to 90°F and a wind of one meter per second was used for cooling. This rating results in about a 20% decrease in panel performance.

Check the panel's PTC rating at **www.consumerenergycenter.org/cgi-bin/eligible_pvmodules.cgi**. Some retailers will include both the STC and PTC ratings.

Check the inverter's CEC rating at **www.consumerenergycenter.org/cgi-bin/eligible_inverters.cgi**. If the retailer includes a CEC rating, this is the PTC rating derated by the inverter efficiency.

Wiring efficiency will vary with the size of the wire and the length of the wire runs. Unless you calculate and specify the wire yourself, figure 97% efficiency.

Links

- **www.consumerenergycenter.org/erprebate/equipment.html**
- **http://abcsolar.com/pdf/2001-09-04_500-01-020.pdf**
- **www.nmsu.edu/~tdi/pdf-resources/A%20Critical%20Look%20at%20PV%20Module%20Grounding2.pdf**
- **www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html**
- **www.zomeworks.com/solar/trackrack/Homepower_june2004.pdf**
- **www.the-mrea.org/download/Off%20GridPVFactSheet.pdf**

In my case, the 187 watt panels were rated at 167 and the inverter was rated at 94%, so I calculated my wiring at 98% efficient. To size my system for 100% utilization, I needed a system rated for

<Daily Consumption (kWH)> / <Hours of full sun> / <inverter efficiency> / <Wiring efficiency> = <system size in kW>

or

20 / 5.8 / .94 / .97 = 3.782 kW CEC.

The selected system should be this size or larger.

Financials of a Solar System

On **www.affordable-solar.com/residential.solar.home.htm**, the Sunwize 5 kW system has a PTC rating of 4.717 kW. The Fronius IG 5100 inverter has an efficiency of 94.5%. This would give a CEC rating of 4.457 kW and a price tag of $35,400 ($7.94/watt) — no small sum.

In addition to financing, there are generally a number of federal, state, and utility rebates that are available — easily totalling many thousands of dollars. Most large solar installation companies will give you the information you need to apply for the rebates and tax credits.

In addition, many companies now offer package deals that will even include assortments of compact fluorescent light bulbs to help you minimize consumption of your freshly converted sunlight!

Conclusion

If you have the itch to "go solar" on your house, now is a great time to take the plunge. Panel efficiencies are higher than ever and the technology/dollar ratio is certainly moving in your favor. With energy prices guaranteed to always steadily increase, this is one capital upgrade to your house that not only adds resale value, but might even earn you a check from the utility company instead of a bill! **NV**

IXOLAR High Efficiency Solar Cells

IXYS renewable energy solutions for your products: Ideal for mobile phones, cameras, PDAs, and more.

Clare's High-Voltage Solar Cell Family

Features:

- Provides true wireless power
- Triggers with natural sunlight or artificial light
- Semiconductor miniature size and reliability
- Replacement of Discrete Components

Applications:

- Portable Electronics
- Solar Battery Chargers and Battery Operated Equipment
- Consumer Electronics
- Off Grid Installation
- Wireless Sensors and Detection
- Self Powered Sunlight/ Light Detection
- Self Powered Products

For samples and more information about Clare's High-Voltage Solar Cell Family, go to http://clareweb2.clare.com/Products/SolarCell.htm

IXOLAR High Efficiency Solar Bits

Features:

- Monocrystalline silicon technology
- High efficiency
- Enhanced light trapping surface texturization
- Voltages to 1.8V

Applications:

- Battery chargers for portables such as cell phones, PDAs, GPS Systems, etc.
- "Green" electricity generation
- Power backup for UPS, Sensors, Wearables

For samples and more information about IXOLAR High Efficiency Solar Bits, go to http://focus.ixys.com/solar.html

IXYS Renewable Energy products are ideal for:

- **Portable electronics**
- **Integrated supplemental power for portable devices**
- **Remote applications**
- **Extended battery life**

Summary Tables for IXOLAR Solar Bits

Clare's High-Volatage Solar Cell Family

Part Number	Open Circuit Voltage (V)	Short Circuit Current (µA)	SOIC Package
CPC1822	4	50	8-Pin
CPC1824	4	100	16-Pin
CPC1831	8	25	8-Pin
CPC1832	8	50	16-Pin
CPC1840	16	12	8-Pin
CPC1841	16	25	16-Pin

IXOLAR High Efficiency Solar Bits

Part Number	Open Circuit Voltage (mV)	Short Circuit Current (mA)	Typical Voltage @ P_{mpp} (V)	Typical Current @ P_{mpp} (mA)
XOB17-12 x 1	0.63	42.0	0.51	39.0
XOB17-04 x 3	1.89	12.6	1.53	11.7

B-suffix: bondable front-side metallization
IXOLAR Solar Dies are also available

IXYS Corporation now offers renewable energy solutions which enhance our position as a global supplier of Power Management Semiconductors with a comprehensive range of Power MOSFET, IGBT, Bipolar, and Mixed-Signal IC solutions that provide improved efficiency and reduced energy cost in a wide range of power system applications. For over twenty years, IXYS has been at the forefront of Power Semiconductor and IC technology having over a hundred patents and innovations in the development of the IGBT, High Current Power MOSFETs, Fast Recovery Diodes, BiMOSFETs™, Reverse Blocking IGBTs, and Gate Driver ICs.

• IXOLAR is a trademark of IXYS Corporation

DATA STORAGE

Techniques, Problems, and Solutions

- **Have you had a USB drive suddenly stop working?**
- **Do you need to continuously backup data or plan to archive a large amount of material?**

by Rick Davis

These situations highlight some very important issues in the field of data storage and getting to the answers can require a variety of information across several areas of technology. However, understanding these topics can greatly help you prepare for any serious storage needs.

In the field of computers and technology, there are many items that carry the name of storage, memory, and other similar names, however, it is data storage that is of importance here. Data storage refers to instructions that form a computer program and the data that the programs manipulate. Without these types of storage, computers would not reach beyond basic calculators.

Just as there are a variety of terms to label these types of storage, there exists an equal variety of data storage types. For purposes of archiving and backups, data storage refers specifically to data stored separately from the computer's motherboard (which would be the primary storage) or, in many cases, stored outside the computer itself in a variety of levels of portability. These include hard disks (secondary storage), as well as optical disks and USB drives (off-line storage) or a combination of these either on a network or some other link not directly part of the computer itself.

Density and Capacity

Probably the first thing anyone looks for when considering data storage is its capacity, or the amount of data that can be stored. The density of the storage medium not only plays a part in pricing, but also in the feasibility of its use.

Storage capacity has travelled an interesting road because computers are binary in nature (either 0 or 1), even though most of the world uses the SI system (a base 10 system). It starts out easily enough in binary with a bit (0 or 1) and then eight of these bits comprise one byte. Now for the sticky part.

One KB (kilobyte) according to the computers would be 2^{10} or 1,024 bytes. However, the prefix kilo is defined as 10^3 or 1,000 units (which has caused a variety of headaches). It's important to understand that every computer operating system imposes a "management surcharge" in order to index and store your data. That means, for example, that for every 4,096 bytes of *your* data on the disk, the OS will wrap it in 64 more so that it can be quickly accessed, verified, etc. This causes confusion when a 100 meg hard drive "formats down" to about 98.4 megs. Chalk it up to the cost of doing business on the disk!

Let's get back to measuring the size of things. Every new unit of measure is simply the old unit multiplied by 1,000. For example; 1,000 kilobytes (KB) equals one megabyte (MB); 1,000 megabytes is one gigabyte (GB); and from there, we move to terabytes (TB) and (just recently) petabytes.

Equally significant to capacity is the density of the data being stored. Density is simply a measure of the amount of data that can be stored in a specific amount of storage medium. For example, a CD-ROM can store 700 MB of data while a DVD-ROM (which utilizes the exact same physical space) can store 4.7 GB (4,700 MB) of data. Higher density is better, but it comes at higher costs.

Latency and Throughput

The two remaining factors to consider: latency (the access time to the stored data) and throughput (the rate at which the data can be transferred). Both of these variables usually carry a separate value when reading or writing data. Their initial values are almost always different from a sustained, or average, value.

Latency is usually measured in fractions of a second and generally not a concern (except in unusually demanding applications). Throughput, on the other hand, has become more significant. When the common file size was under 1 MB, it was fine if the computer needed a full second or two to transfer the data. But now, with files reaching into the tens of GB and beyond, even a small difference in transfer rate can be the difference between hours and days when large volumes are being transferred.

Comparisons

There are a few things to keep in mind when comparing the types of storage. First, it is not easy to compare data that is archived with data that needs to be accessed on a regular basis. And things will get more complicated when storing data for multiple users.

Hard Disk

Hard disks are always needed for the regular operation of a computer system. And now it may be possible to archive large amounts of data on these as well. Individual drives are now approaching the 1 TB mark and smaller models are becoming inexpensive.

Multiple drives can be placed into an external enclosure and brought wherever needed, making a very cost effective and portable storage system.

The workings on a hard disk are simple. Each disk is comprised of a number of platters which are like smaller, metallic CDs. Platters have a magnetic coating and are accessed by applying a magnetic field from a rapidly moving read/write head. Increasing the storage capacity while keeping the physical size of the drive the same involves the ability to write data at ever decreasing sizes, the ability to include more platters per drive, or a combination of the two.

Manufacturers will state that the drives are only intended for three to five years of use. This is because the miniature parts can only withstand so many start and stop cycles before breaking down and colliding with the platters. The manufacturer's warranty usually is set to an average time where the possibility of this failure would rise above 50 percent. At that point, collisions begin to cause decreases in speed, as well as failing sectors on the disk.

Optical Disk

Recently, optical disks have been a shaky area for data archiving because of the rapidly evolving and changing formats. Someone who placed a large amount of data on CD-Rs must now re-archive the data onto DVD-Rs. Although it's nice to need less disks, it does take time to set up new equipment and transfer the data.

An optical disk has data literally burned into it by a laser where hard disks have data magnetically written. This technology results in the ability to store more data in the same physical space.

Manufacturers initially claimed the stability of optical disks upwards of 100 years, but this may not be a valid assessment. To be fair, in a perfect world where your data disk is stored in a dark, dry, and untouched place (basically hermetically sealed), it would last a century or more. In the real world, light, heat, and movement all contribute to the degradation of the data stored. Since different types of dye and materials that all affect lifetimes are employed, it's impossible to cast a general timeframe on life expectancy.

Flash Memory

For frequent backups as well as storage of small file types, Flash drives are the ticket. Their portability and ruggedness is also very appealing.

Flash memory can refer to data storage such as memory cards, memory sticks, USB drives, jump or thumb drives, and others. Flash drives have no moving parts and data is stored through the electronic circuits inside.

USB devices have a universal format, however, a Flash card from a smaller digital camera may not be readable through a laptop or cell phone without an adapter.

Flash memory also begins to wear out after a certain number of cycles. As this number is reached, read, write, and general access times will become noticeably slower.

Bigger Storage Options

Regular computer users who constantly need to back up data or keep a large archive have a couple options to consider: the hard disk array and the optical disk library.

Just as the name implies, the hard disk array takes the form of a number of hard disks. Network Attached Storage (NAS) units are stand-alone enclosures and are currently available on the market.

All of the data is always connected to your computer system, so it can be searched and replaced very easily. A potential downside to this setup is that if a drive becomes corrupted or fails, all the data may be lost — thus the creation of RAID, a redundant array of inexpensive disks. There are many forms but the basic idea is to cleverly duplicate the data over other physical drives, thus allowing a single drive failure to be recoverable.

An optical disk library takes the form, not too surprisingly, of a collection of optical disks. You would need an optical disk drive attached to the system to be archived and then the proper number of disks to handle the data.

The upside to this option is the low cost of the disks. A blank disk is well under a dollar. A downside is that accessing the data requires the physical insertion of a specific disk (as with any form of removable media).

When deciding between these two options, consider factors such as capacity needed, frequency of archives, and accessibility to stored data.

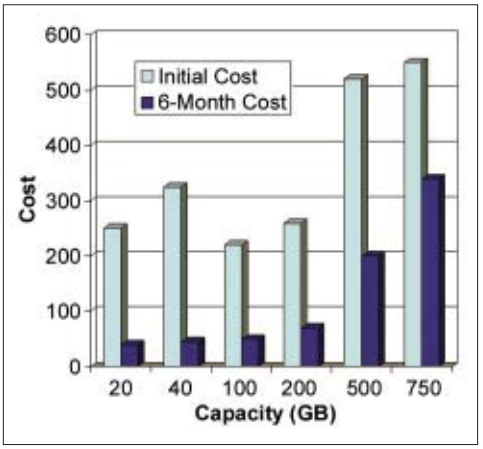
Future

As new technologies become available to store more data in less physical space, the cost to store data will drop. Research in areas of chemistry and physics will mix with advances in digital, electronic, and mechanical engineering to bring even more dynamic advances in data storage.

One such area already in research labs is a three-dimensional holographic storage. This device aims to start at a storage density of 200 GB per cubic inch and eventually max out above 10,000 TB per cubic inch ... all while keeping its cost equal to today's top hard disks.

Also in the works are molecular memories which use special compounds to store electric charges that represent data; basically a chemical Flash drive although with much higher capacity and density. These advances along with the continued development of larger capacity disks (some consumer models boast 750 GB) and optical disks which can store 50 GB, promise to keep sizes smaller and prices lower, so you will get more bang for your buck.

Whatever course data storage takes, it is working hard to keep up with other areas of advancing technology because as the world moves forward, the need to store and recall data will continue to grow. **NV**



Understanding Digital Buffer, Gate, and Logic IC Circuits

by Ray Marston

PART 5: Mixed Gate and Special-Purpose Logic Gate Circuits

Ray Marston describes practical digital mixed gate and special-purpose logic gate ICs such as 'programmable logic, majority logic, and digital transmission gate types in this final episode.

The first four parts of this series explained modern TTL and CMOS logic gate basics and gave practical descriptions of some of the most popular digital buffer, inverter, AND gate, NAND gate, OR gate, NOR gate, EX-OR gate, and EX-NOR gate digital ICs that are available. This month, we expand on this theme and describe a variety of popular digital mixed gate and special-purpose logic gate ICs such as programmable logic, majority logic, and digital transmission gate types that are available from either your local supplier or from specialist dealers.

FIGURE 1. Functional diagram of the 7454 four-wide two-input AND-OR-INVERT (AOI) gate IC.

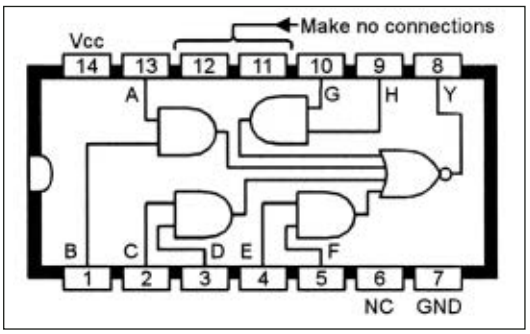
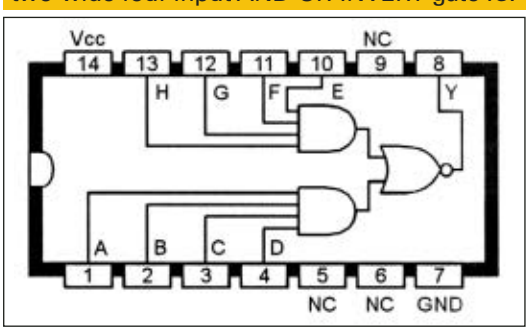


FIGURE 2. Functional diagram of the 74LS55 two-wide four-input AND-OR-INVERT gate IC.



Practical Mixed-Gate Digital ICs

The 74 and 4000B ranges of digital ICs include a number of mixed gate types that contain gates of more than one type, wired together for use in special applications. The best known of these are AND-OR-INVERT (AOI) gates, and examples of two of these are shown in Figures 1 and 2. It is unlikely that you will ever need to use an AOI gate, but you may find it useful to learn some of the jargon that is associated with them.

Looking first at the 7454 IC of Figure 1, note that it has input connections to four two-input AND gates, and this accounts for the four-wide two-input AND- part of the IC's title; also note that the outputs of these four AND gates are wired to the input of a NOR gate and hence made externally available via pin 8. Now, a NOR gate is simply an OR gate with an inverted output, and this fact accounts for the OR-INVERT part of the IC's title. Thus, an AND-OR-INVERT gate is simply an AND-NOR gate with a rather flowery title. The action of the 7454 IC is such that its output is normally high, and goes low only when both inputs to one or more AND gates are high.

Turning next to the 74LS55 IC of Figure 2, note that this has input connections to two four-input AND gates, and this accounts for the IC's two-wide four-input AND-OR-INVERT title; the IC's action is such that its output is normally high, and goes low only when all inputs to at least one AND gate are high.

Returning briefly to the 7454 IC, note that this is a standard TTL device, and its data sheet carries a very sinister warning that NO EXTERNAL CONNECTIONS must be made to pins 11 and 12. Also note that 'LS' versions of this device (the 74LS54) have two of its four AND gates configured as two-input types and two configured as three-input types, and is sometimes known as a four-wide, 2-3-3-2-input AND-OR-INVERT gate. It has pin connections that differ from those shown in Figure 1.

A Programmable Logic IC

Most logic ICs are dedicated devices that contain a number of fixed gates. One very useful exception is the

OUTPUT FUNCTION	Ka	Kb	Kc	UNUSED INPUTS
NOR	0	0	0	0
OR	0	0	1	0
OR/AND	0	1	0	0
OR/NAND	0	1	1	0
AND	0	1	1	0
NAND	1	0	0	1
AND/NOR	1	1	0	1
AND/OR	1	1	1	1

Kd = 1 for Normal action
= 0 for High-Z outputs
EXPAND input = 0

FIGURE 4. Function control diagram of the 4048B eight-input gate IC.

CMOS IC known as the 4048B programmable eight-input multifunction gate (see Figure 3). This modestly priced (but hard to find) 16-pin IC has two groups of four input terminals, plus an expansion input terminal, and is provided with four control (K) pins which let the user select the mode of logic operation, plus a J output terminal that enables 4048B ICs to be cascaded, so that two of them make a 16-input gate, or four make a 32-input gate, and so on.

Control input pin Kd (pin 2) enables the user to select either normal or high-impedance three-state output operation. The remaining three binary control inputs (Ka, Kb, and Kc) enable any one of eight different logic functions to be selected, as shown in the table of Figure 4, which also shows how to connect unwanted inputs in each mode of operation. Thus, to make the 4048B act as a normal six-input OR gate, connect the two unwanted inputs to ground (logic 0), connect Ka and Kb to ground, and Kc and Kd to the positive supply rail. The EXPAND input (pin 15) is normally tied to ground.

Eight different logic functions are available from the 4048B, as shown in Figure 5. Operation in the AND, OR, NAND, and NOR modes is quite conventional, but operation in the remaining four modes (OR/AND, OR/NAND, AND/OR, and AND/NOR) is less self-evident. In the latter cases, the inputs are split into two groups of four, each of which provides the first part of the logic function, but the pair of groups provide the second part of the logic function. Thus, in the OR/AND mode, the IC gives a high output only if at least one input is present in the A-to-D group at the same time as at least one input is present in the E-to-H group, etc.

The EXPAND input terminal of the 4048B enables ICs to be cascaded; thus, two ICs can (for example) be made to act as a 16-input gate by feeding the output of one IC into the EXPAND terminal of the other. Note when using expanded logic that the input logic feeding the expand terminal is not necessarily the same as the overall logic that is required. Thus, an OR expand input is needed for expanded NOR or OR operation, a NAND expand for AND and NAND operation, a NOR expand for OR/AND or OR/NAND operation, and an AND expand for AND/OR and AND/NOR operations.

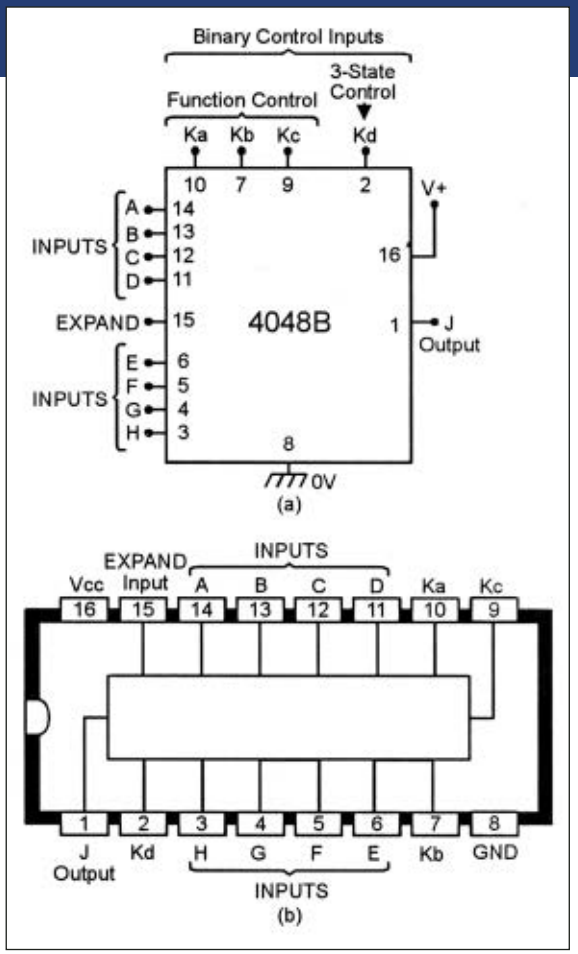
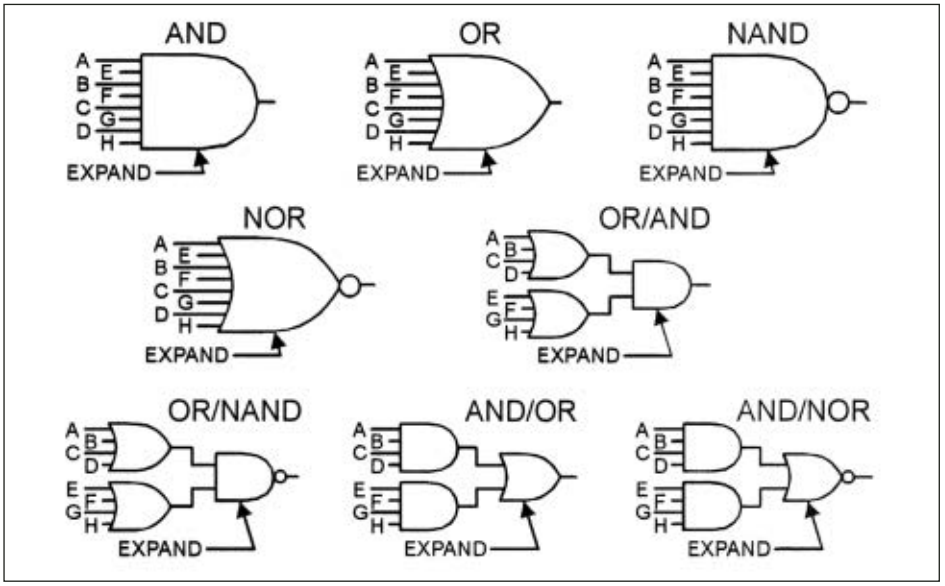


FIGURE 3. Functional diagram (a) and outline (b) of the 4048B multifunction expandable eight-input gate IC.

Majority Logic Circuits

One little known but useful type of logic system is majority logic, in which the logic device has an odd (3, 5, 7, etc.) number of inputs and gives an active output only when the majority of these inputs are high, irrespective of which inputs are high. This type of logic is useful in pseudo-intelligent alarms and robotic devices, etc., and

FIGURE 5. The eight basic logic functions of the 4048B IC.



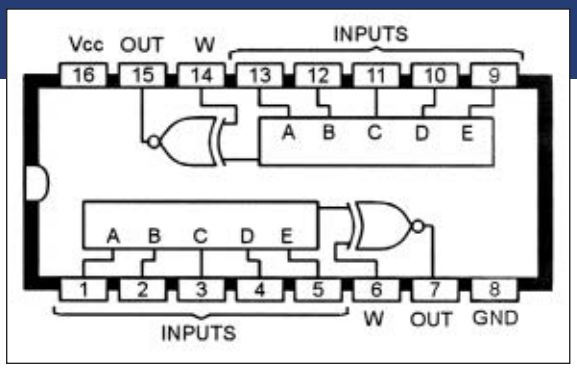


FIGURE 6. Functional diagram of the 4530B dual five-input majority logic gate IC.

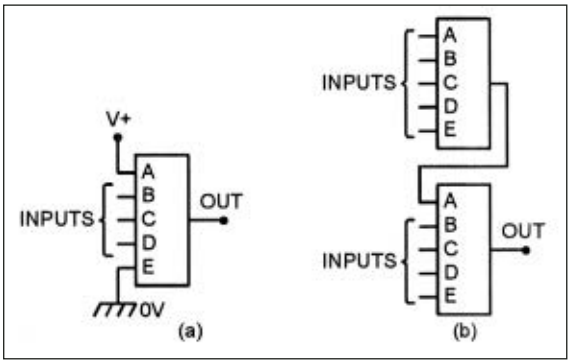


FIGURE 7. The number of effective inputs of a majority logic circuit can be (a) decreased or (b) increased easily.

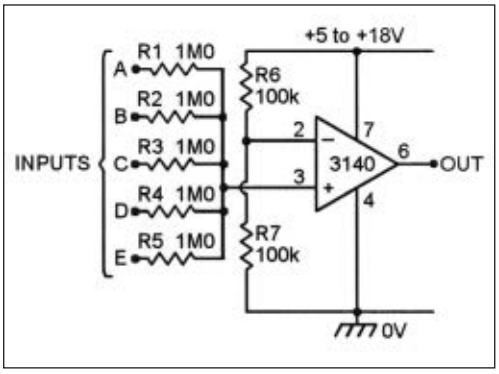


FIGURE 8. Simple five-input op-amp majority logic gate.

may (for example) sound an alarm bell only if at least two of three detectors indicate a fault condition, or enable a robot to move only if there is more stimulus to move than there is to stand still, etc.

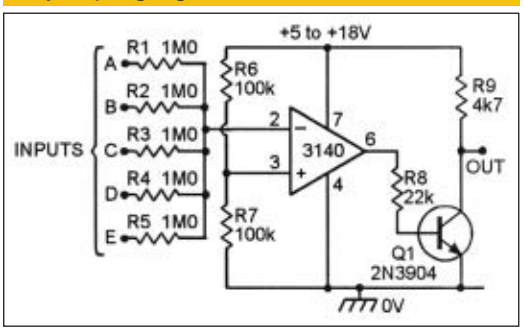
The best know CMOS majority logic IC is the 4530B dual five-input unit (Figure 6), each half of which contains a five-input majority logic element with its output feeding to one input of an EX-NOR gate that has its other input (W) externally available, enabling it to be wired as either an inverting or non-inverting stage. Thus, when W is tied to logic 1, the EX-NOR stage gives non-inverting action and the element's output goes high only when the majority of inputs are high. However, when W is tied to logic 0, the EX-NOR stage gives an inverting action and the element's output goes high when the majority of inputs are low. Note that the effective number of inputs of a 4530B element can be reduced by wiring half of the unwanted inputs to logic 1 and the other half to logic 0, as in Figure 7(a). Alternatively, the effective number of inputs can be increased by cascading elements, with the output of one element feeding one input of the cascading element, as in Figure 7(b).

In practice, the 4530B IC is often hard to find. In this case, a majority logic circuit can easily be built by wiring a 3140 CMOS op-amp in the basic configuration of Figure 8, which shows a five-input circuit. Here, the op-amp functions as a voltage comparator in which R6-R7 applies half of the supply voltage to pin 2 of the op-amp, and the five input resistors (which must each be connected to either ground or the positive supply rail) form a potential divider that applies a fraction of the supply voltage to pin 3.

This pin 3 voltage is lower than that of pin 2 if the majority of inputs are low, but greater than that of pin 2 if the majority of inputs are high. Under this latter condition, the op-amp output switches high, and this gives majority logic action.

Note that if 5% resistors are used, the Figure 8 circuit can be given any odd number of inputs up to a maximum of 11 by simply adding one more 1 meg resistor for each new input. The output of this circuit switches almost fully to zero volts when the output is low, but only rises to within a couple of volts of the positive rail when the output is high. In most applications this defect is of little importance; it does mean, however, that elements cannot be cascaded to increase the total number of inputs. This defect can be overcome by using the alternative configuration of Figure 9, in which the output is inverted and level-shifted by Q1, and the inputs to the op-amp are transposed. The output of this circuit switches to within 50 mV of either supply rail, enabling units to be cascaded without limit.

FIGURE 9. Compound five-input op-amp majority logic gate.

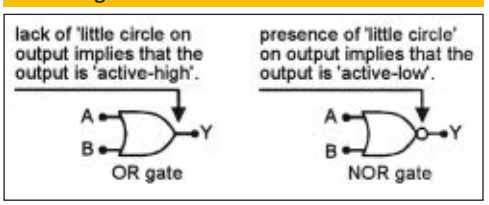


Assertion-Level Logic Notation

The reader is already familiar with the fact that an AND or OR gate has an active-high output (i.e., the output of an OR gate goes high when any input is high, etc.), and with the MIL/ANSI convention that the addition of a little circuit to an OR gate output (etc.) implies that the gate has an active low output, as shown in Figure 10. Technically, the presence or absence of this little circle is known as assertion-level logic notation, and can be legitimately applied both to the input or the output of a logic symbol.

Thus, the crude gated pulse generator symbol of Figure 11(a) implies that the pulse gen-

FIGURE 10. Basic principles of assertion-level logic notation.



erator is gated on by a high input signal, but the modified symbol of (b) — in which a little circle is added to the generator's input — implies that this generator is gated on by a low input signal, etc. Note that in practice the (a) generator can be made to give the same action as that of (b) by simply inserting an inverter stage between the IN terminal and the input of the generator, as shown in (c), so that a low input forces the generator's input high and gates it on. This system of assertion-level logic notation is, in fact, widely used in electronic logic symbology; some examples of its use are shown in Figure 12, which deals with mixed logic equivalents.

Mixed Logic Equivalents

When assertion-level logic notation is applied to a simple two-input AND or OR gate, it can be quickly seen that the gate has four possible input assertion-level sets, i.e., both inputs active-high, or both active-low, or one active-high and one active-low, or vice versa. Similarly, the gate's output has two possible assertion-levels (active-high or active-low). Thus, a two-input AND or OR gate has a total of eight possible input/output assertion levels.

If Truth Tables are drawn up for all 16 possible AND and OR gate variations, it becomes apparent that each AND gate variation has a mixed-logic OR gate equivalent, and vice versa, as shown in Figure 12. Note in particular that a normal AND gate can be simulated by a NOR gate with both inputs inverted, and that a normal OR gate can be simulated by a NAND gate with both inputs inverted, etc.

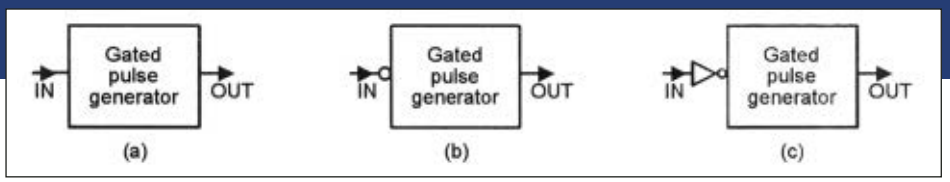


FIGURE 11. Pulse generators that can be gated-on by (a) logic 1 and (b,c) logic 0 inputs.

Digital Transmission Gates

Most logic gate circuits presented in this five-part series show the gates used as simple logic state detectors.

FIGURE 13. Four basic types of digital transmission gate, with their two-input logic equivalents.

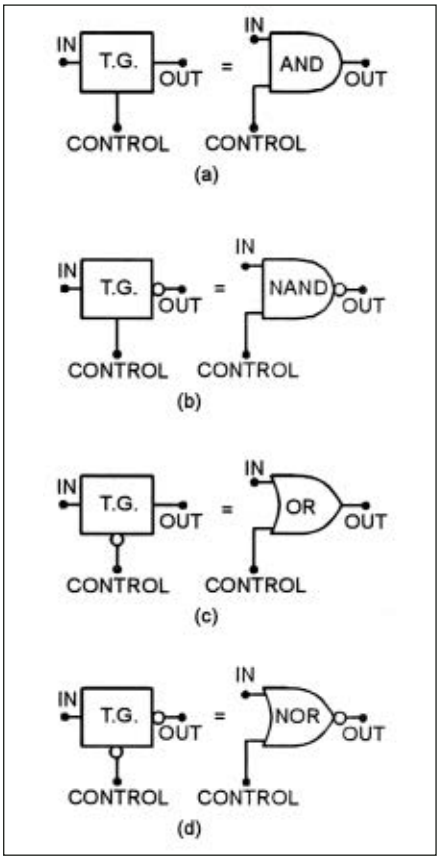
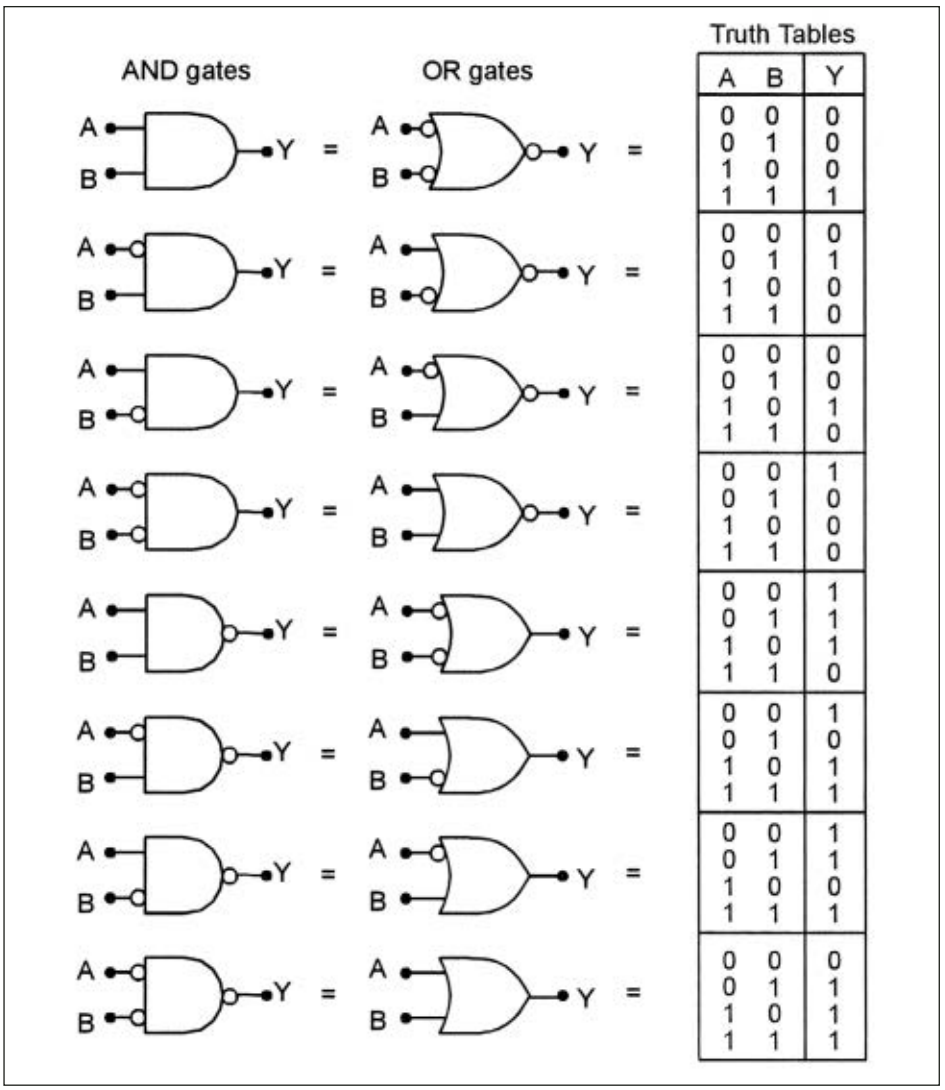


FIGURE 12. Mixed logic equivalents.



Truth Tables

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1
0	0	0
0	1	1
1	0	0
1	1	0
0	0	0
0	1	0
1	0	1
1	1	0
0	0	1
0	1	0
1	0	0
1	1	0
0	0	1
0	1	1
1	0	1
1	1	0
0	0	1
0	1	1
1	0	1
1	1	1
0	0	1
0	1	1
1	0	1
1	1	0
0	0	0
0	1	1
1	0	1
1	1	1

Two-input AND, NAND, OR, and NOR gates can, however, also be used as digital transmission gates which pass a digital input signal only when they are opened by an appropriate control signal or logic level.

Transmission gates are available in four basic types, and the logic symbols of these are shown, together with their logic gate equivalents, in Figure 13. The basic transmission gate (a) gives a non-inverted output, can be opened by a logic 1 control signal, and can be simulated by a two-input AND gate. This transmission gate can be made to give an inverted output, as in (b), by using a NAND gate instead of an AND gate. Another variation of the basic transmission gate is shown in Figure 13 (c); it gives a non-inverted output but is opened by a logic 0 control signal, and can be simulated by a two-input OR gate. This gate can be made to give an inverted output, as in (d), by using a NOR gate instead of an OR gate.

Finally, to conclude this final part, Figures 14 to 17 show the precise relationships between the input, output, and control signals of each of these four types of digital transmission gate. **NV**

FIGURE 14. AND-type transmission gate is opened by logic 1 control and gives normally-low, non-inverted output.

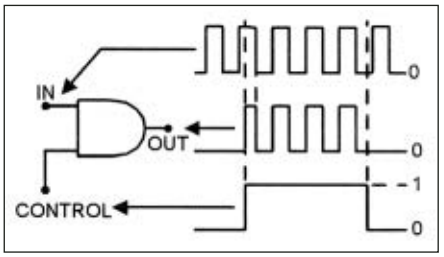


FIGURE 15. NAND-type transmission gate is opened by logic 1 control and gives normally-low, high-inverted output.

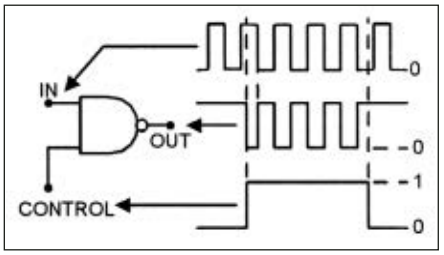


FIGURE 16. OR-type transmission gate is opened by logic 0 control and gives normally-high, non-inverted output.

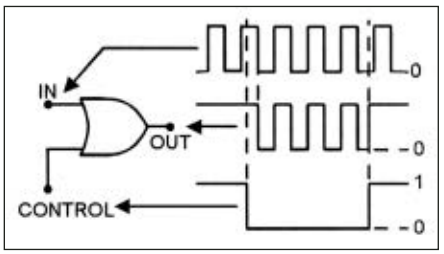
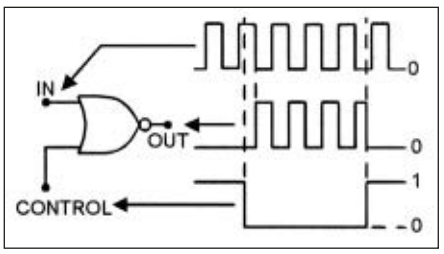


FIGURE 17. NOR-type transmission gate is opened by logic 0 control and gives normally-low, inverted output.



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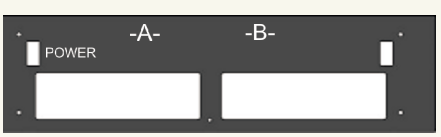

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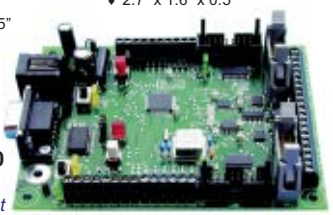

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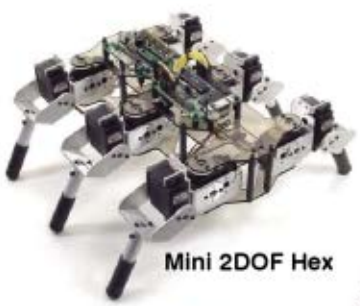

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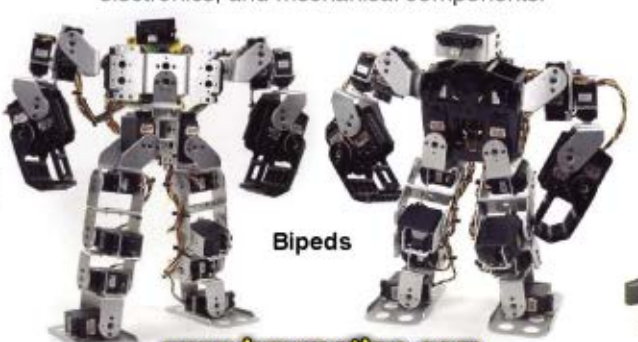

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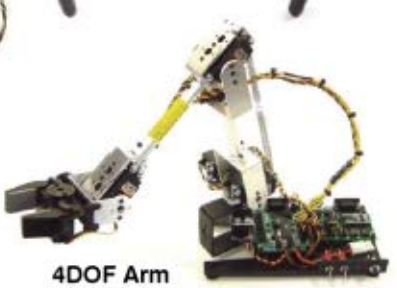

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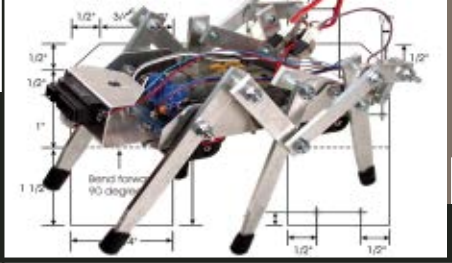


■ GUEST HOSTED BY BRYAN BERGERON

BIOLOGICALLY INSPIRED ROBOTS

DEVELOPERS OF BIOLOGICALLY INSPIRED ROBOTS borrow from systems and methods found in nature with a goal of producing a more efficient, capable, or cost-effective robot than would be possible through traditional means. Popular examples of biologically inspired robotics or biomimetics include the hexapod and quadrapod robots used to traverse uneven terrain, snake robots that can swim or wriggle through tight spaces, and mole robots that can make their way through rubble in search of disaster victims. This article explores biomimetics and offers suggestions of how to modify the popular Stiquito hexapod walker.

BIOMIMETICS

Biological principles often suggest solutions to challenges that seem insurmountable using traditional robotics technologies and approaches. For example, one of my recent projects involved designing a robot capable of burrowing a meter deep in soil while consuming only a couple hundred watt-hours of energy. Initial prototypes used an auger drill assembly on the head of a snake robot, but methods of stabilizing the body of the robot proved too inefficient.

After reviewing several diggers in nature — from mole locusts and snake lizards to English moles — the oscillating head of the snake lizard or amphisbaena showed the most promise. The final decision to go with a design suggested by the snake lizard was based in part on a qualitative model of a robot using a snake lizard head. The graphic model of the snake lizard robot burrowing through various types of soil was developed using Physx' physics game engine and an inexpensive game shell [1].

■ FIGURE 1. Biomimetic digger robot based on the snake lizard.

The worm lizard is a phenomenal digger despite its small size. Instead of relying on an auger drill bit, water jet, or ultrasonic drill, the digger uses side-to-side head movement of its specially shaped head to compact the material to either side, making room for the robot body. Figure 1 shows a physical model of the robot head digging through layers of rice and dyed barley. Note the disruption pattern extends several times the diameter of the oscillating head along the plane of oscillation. As with the snake lizard, the physical model showed the extent of horizontal disruption and rate of penetration — both factors in defining energy requirements — vary with the type of head movement, the oscillating frequency, and the structure of the robot head.

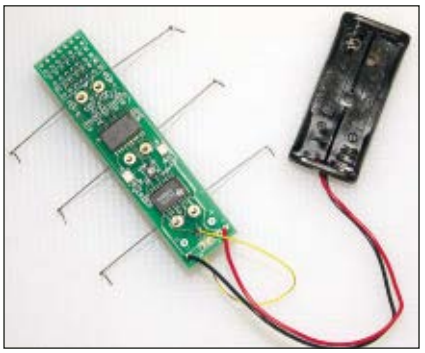
One of the most impressive biomimetic robots under development is DARPA's BigDog Multifunction Utility/Logistics Equipment Vehicle (MULE), which is designed to transport equipment and supplies over rough terrain that would stop a wheeled vehicle. The gasoline-powered, 75 kg quadrapod is being developed by Boston Dynamics, Foster Miller, the Jet Propulsion Laboratory, and the Harvard University Concord Field Station. According to Boston Dynamics, BigDog can trot at 3.3 mph, climb a 35 degree slope, and carry a 120 lb load [2].

STIQUITO

You don't have to have a multi-million dollar DARPA to explore biomimetics. If you're new to crawling robots, then consider the Stiquito, which is modeled after the walking stick insect (see Figure 2). A complete robot kit, including *STIQUITO Controlled!* — a comprehensive textbook that covers programming and construction of the shape memory alloy-based propulsion system — is available from Amazon for less than $50 [3].

Onboard processing is provided by a TI MSP430F1122 programmable microcontroller, which has 256 bytes of RAM, four Kbytes + 256 bytes of Flash memory, a 16-bit timer, 10-bit A/D converter, and 14 I/O pins.

Unlike the servo-based hexapod robots such as the CrustCrawler HexCrawler and LynxMotion BH3, the Stiquito relies on Nitinol® shape



■ FIGURE 2. Stiquito hexapod with AAA battery pack.

■ FIGURE 3. Floam microbead compound.

memory alloy wire for propulsion. The wire contracts when heated and returns to its original length when cooled — assuming an opposable force is available to stretch the wire back to its original size. This force is supplied by the Stiquito's music wire legs, and the heat is generated by current through the Nitinol wire.

In operation, the microcontroller actuates two wires on one side and one on the other side creating a tripod support. The pattern is then reversed and the robot moves forward and momentarily rests on the second tripod support. The pattern and pace can be modified by programming the onboard microcontroller, as described in *STIQUITO Controlled!*.

WATER STRIDER MOD

The bare-bones Stiquito is an impressive learning environment and — within the limits of its load bearing carrying capacity — a good experimental platform, as well. Continuing the theme of biomimetics, we can use the Stiquito as the basis for a water walker inspired by the Water Strider, an insect that floats on water by virtue of microscopic hairs or setae on its legs that trap tiny air bubbles [4,5].

For the air bubbles, we'll substitute the microbeads within Floam — a self-adhesive craft compound available in toy stores and online (see Figure 3). The compound, which has the consistency of fish eggs when wet, air-dries to a rigid, extremely lightweight foam. Granted, you could simply insert the wire leg ends into precut cubes of closed cell foam, but once you get the hang of Floam, you'll find numerous applications in your robotics work.

Start the mod by coating the Stiquito battery pack and leg ends with a 1/4 inch layer of Floam. Wait a few hours and apply another layer. You can also use the Stiquito with a tethered power supply to avoid having to coat the battery pack with Floam. Make certain to angle the Floam feet parallel to the bends in the wire so that the Stiquito will move forward. Allow the Floam to dry overnight and then coat with clear nail polish or other lightweight sealant.

You'll find Floam useful in creating biomimetic robots because it can be molded into organic shapes. For structural components, consider covering aluminum tubing or screen with the compound for added support with little weight penalty. It's also useful for cradling laser rangefinders and other impact-sensitive sensors.

For your first test run, try the Water Strider in a shallow pan with about 1 cm of water — without the batteries installed. If your robot sinks to the bottom of the pan, you'll need to add more Floam. If you've opted to pull the two AAA batteries behind the Water Strider, then make certain you test the flotation of the Floam-coated battery compartment, as well. On subsequent runs, try reprogramming the microcontroller for different stride sequences in an attempt to maximize speed in the water.

You might ask yourself why go through the trouble of creating a faux Water Strider when a plastic boat with an underwater screw is faster and simpler to construct. Granted, the standard technology may be superior in some cases, but the Water Strider generates a smaller wake and audible signature than a motor-powered boat screw. Both factors could be critical in a stealth military application or for something as simple as a platform for a fish sensor. **NV**

REFERENCES

■ [1] B. Bergeron. Physics-Based Animation for Qualitative Assessment of Biomimetic Subterranean Burrowing Behaviors. 2007. IEEE CIRA 2007.

■ [2] **www.bdi.com/content/sec.php?section=BigDog**

■ [3] J. Conrad, *STIQUITO Controlled!* 2005: IEEE Press.

■ [4] R. Britt. *Walking on Water: Insect's Secret Revealed*. Live Science, 2004 [cited 2007 June 21]; Available from **www.livescience.com/animals/041103_water_strider.html**.

■ [5] X. Gao and L. Jiang, *Biophysics: Water-repellent legs of water striders*. Nature, 2004. 432(7013): p. 36.

RESOURCES

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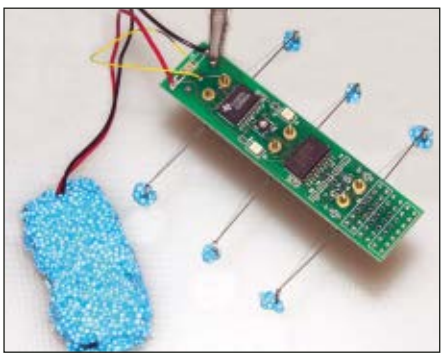
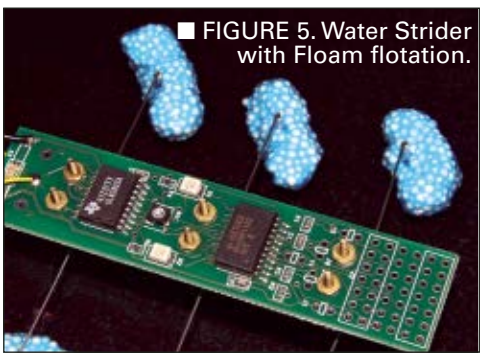
■ CrustCrawler HexCrawler — **www.crustcrawler.com**

■ Lynxmotion BH3 hexapod — **www.lynxmotion.com**



■ FIGURE 4. First layer of Floam on the Stiquito.



■ FIGURE 5. Water Strider with Floam flotation.

■ BY CHUCK HELLEBUYCK

BasicATOM IN-CIRCUIT DEBUGGER

IF YOU'VE THOUGHT ABOUT GETTING STARTED with PIC® microcontrollers (MCUs), you've probably seen the variety of available development tools, such as programmers, debuggers, and the Integrated Development Environments (IDEs). To a beginner this can be very confusing, because there are Microchip's own tools and also many from third party suppliers — and the prices range from a few dollars to thousands of dollars. I get emails from beginners who have seen this and wonder what they should buy. They want to get started, but don't want to spend money on a tool and then find out they didn't need it or later learn that it was intended for the advanced user. One of the reasons that I like to recommend Basic Micro's BasicATOM chips for the beginner is because of the great In-Circuit Debugger (ICD) built into the BasicATOM software.

We all can understand what a programmer does, and I've talked about various options in previous articles. The IDEs are typically free to download and each compiler has its own version. Microchip has an IDE that works with all PIC MCUs and all the Microchip development tools called the MPLAB® IDE, and it's free to download.

Debuggers are a bit harder to understand for the beginner and, often times, are some of the most expensive tools available. They are priceless, though, if you are trying to understand why your code doesn't work properly. They offer the ability to step through your code, command by command, or set breakpoints.

Breakpoints are like stop signs to software. They will halt a program at the place where the breakpoint is set. Typically, you would set a breakpoint at the section of software where you suspect an error. Once it stops there, you can single step through the commands to see if they're doing what you expect. Debuggers also will display the value of the variables in your software and special function registers inside the PIC MCU.

Using a simple BasicATOM DEBUG command will allow you to send variable data out of the serial connection to a PC screen but, being able to see deeper inside the chip and step through your code slowly as you watch the hardware react, really helps get to the root cause of your code problems. It also gets a bit tiresome having to inject DEBUG commands throughout your program, as you try to figure out what's going wrong.

The BasicATOM chips and modules offer a built-in ICD feature that displays all the inner registers and variables; plus, it includes the single stepping breakpoints and other typical debugger features. The best part is that the BasicATOM debugger is included for free. All you need to do is download the BasicATOM programming software (IDE) from the **BasicMicro.com** website, and connect your PC to a BasicATOM chip or module, and you're ready to go. This article will cover the debugger in a little more detail, so you can see how great this feature is.

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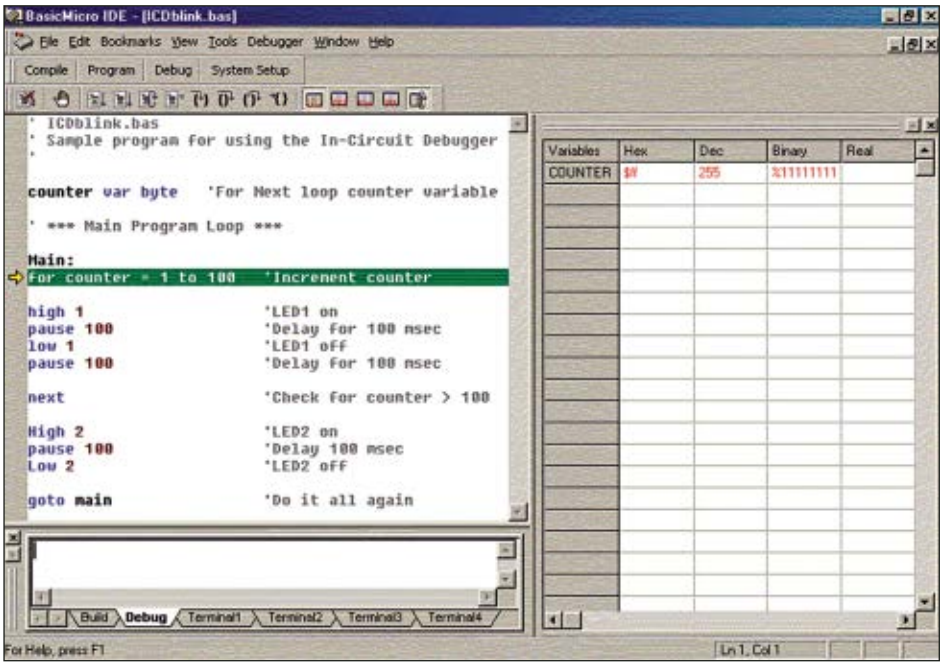
IN-CIRCUIT DEBUGGER

The BasicATOM ICD is like a special tool that makes your software run in slow motion to make it easier to determine where an error might have occurred. Once you use it, you won't ever want to develop without a debugger again.

The BasicATOM ICD is completely controlled by software. No additional hardware is required. When you have completed a program, you would normally press the "Program" button to compile and download your program into the BasicATOM chip/module. To use the ICD, you simply press the "Debug" button, instead.

The difference between the Program button and the Debug button is hidden. They both compile and then program the BasicATOM chip/module, but the Debug adds another hidden step — it adds a block



■ FIGURE 1. The BasicATOM with the ICD enabled.

of code to your program that is used by the ICD.

When your program is running, the added ICD block of code sends variable values, internal register values, and other details to the PC through the programming cable. The ICD — which is built into the programming screen IDE — will display that data in the way you choose, for example, by clicking on the different setup buttons in the ICD debug tool bar. The debugger controls allow you to run the program continuously or in animate mode, which automatically steps command by command in slow motion through the program.

You can also manually step through your code command by command by using the PC mouse to advance the program via the various single-step buttons. This gives you total control of how the program advances. Figure 1 shows the BasicATOM IDE with the debugger enabled.

As mentioned, the ICD allows you to view the state of each variable and each output state, and even allows you to monitor the inner workings of the BasicATOM chip/module. (It helps to have knowledge of the PIC16F876A or PIC16F877A microcontroller, from which the BasicATOM chip is built). The ICD screen shown in Figure 1 is a program running in DEBUG mode.

IMPORTANT NOTE

When the ICD is running in the BasicATOM chip/module, the running program can have an added delay, from 0.5 milliseconds to 500 milliseconds, depending on the action requested in the ICD. You must take this into account when running time-critical code. Each command will run in full runtime mode (SERIN and SEROUT will function normally), but added time will appear between commands. Also, the programming cable must be connected to the PC, or the debugger will not operate and neither will the BasicATOM chip/module.

■ FIGURE 2. The BasicATOM ICD toolbar.

ICD CONTROLS

The ICD controls can be found under the Debugger selection in the top menu line, or via the debugger toolbar line that appears when you press DEBUG to compile your program. The debugger toolbar line can be switched on and off under the View main menu selection. The total toolbar is shown in Figure 2. A summary of the ICD control features follows.

Connect/Disconnect

The Connect/Disconnect button is used to establish communication between the ICD and the BasicATOM chip/module. When the DEBUG button is pressed and the program is downloaded, the ICD will automatically connect to the BasicATOM chip/module. A green bar will highlight the first line of the program indicating that the ICD is successfully connected. The connect/disconnect icon will change to Disconnect, so you can disconnect the ICD from the BasicATOM chip/module at any time by just clicking on this icon.

Toggle Breakpoint

The Toggle Breakpoint button allows you to turn a breakpoint on or off at any point in the program. A breakpoint is a highlighted line that will stop execution of the program when it gets to the designated command line. This is handy if you want to see what the variables and I/O pins look like when a specific command is encountered in the program, without having to step through each command.

To use it, just position the cursor on the line where you want the program to stop. If a breakpoint is not set on that line, click on this icon or right click on your mouse and select Toggle Breakpoint. This will highlight the designated command line in red and enable the breakpoint action. To turn it off, just click on the icon again or right click to turn it off.

Animate

This is a nice feature of the ICD. The Animate function will automatically step through your program, command by command, in slow motion. Each command being executed is highlighted in green. When the command is completed, the next line is highlighted. This allows you to

watch and verify that the program is flowing where you expect it to go.

If the "Auto Update" feature is selected (described below), then variables and internal information will be updated after each command. To view those values, though, it is often best to pause the program, as the animate mode can sometimes run too fast to allow you to read the data.

Run

This option allows you to run the program in the BasicATOM chip/module at full speed (minus a minor delay for the debugger block of code), without stopping to check for variables or other data. The green command-line indicator will not step through each command. It will just stay at the last line executed, before the Run icon was pressed.

Reset

Reset is used to start the program at the beginning. Any information stored in variables is not erased. This is a simple way to start at the beginning or to see how your program will react if a hardware reset were to occur.

Pause

The Pause button will halt the program at the current command line. To resume execution, the run or animate button is pressed. The pause button is handy to stop the run or animate mode, so variables and other data can be viewed.

Step Into

This is the button you press to step through your program, command by command, using your PC mouse.

Step Over

This button is a special step button that allows you to jump over a part of the program, such as a GOSUB or FOR-NEXT routine. Sometimes a GOSUB or FOR-NEXT routine will take many clicks of the mouse to get through, using Step Into. This allows you to jump over the designated routines and move on to the command lines after them.

Step Out

This is another special step button that allows you to leave a GOSUB routine. It's handy for looking at part of a GOSUB routine, and it lets you leave when you have seen enough. Clicking this will jump you to the command line after the end of the GOSUB routine.

Run To Cursor

Clicking on any command line in the program will produce a blinking cursor. If you then click on the Run To Cursor button, the program will execute in RUN mode until the cursor line is encountered. The program execution will stop at that command line.

Show Variables

This control button will toggle the Variables window open or closed. When it's selected, a separate window will open and the variables defined in your program will automatically be listed. The values of those variables will be displayed in hex, decimal, and binary formats. (Make sure auto update is selected, so these are updated after every command).

Show SFRs

SFRs stands for Special Function Registers. These are special internal locations within the BasicATOM chip that indicate how the internal program is responding to your modifications of the internal PIC MCU registers. This is really a function for the advanced user, but can be handy for understanding how the BasicATOM Basic program controls the PIC MCU.

Show RAM

This feature shows all the Random Access Memory in the BasicATOM chip/module, not just the variables. This is also handy for the advanced user to see the inner workings of the PIC MCU.

Show Gosub Stack

This displays the GOSUB stack. The GOSUB stack is the list of location pointers within the Microchip PIC MCU that directs where to return to when the subroutine is completed. By monitoring this, you can see how GOSUBs have nested, verify where you came from, and make sure that you're not somehow getting lost. This is really an advanced user function.

Set Auto Update

This should always be selected. It tells the ICD to update the variable, RAM, SFRs, and stack after every command is executed. You should select this when the debugger is first connected, but it can be turned on or off anytime.

ICD EXAMPLE

I want to show an example of using the ICD. This is a very simple program written to flash the LEDs on my Ultimate OEM module with the BasicATOM 28B chip installed. The program will flash LED1 on the Ultimate OEM 100 times and then light LED2, before looping back to do it all again. The variable counter stores the number of flashes, so we can use the ICD variable window to watch the counter variable value change. The program is shown in Listing 1.

ENTERING ICD DEBUG MODE

To get started, the program is typed into the editor window. When that's done, make sure the Ultimate OEM BasicATOM module is connected to the programming cable and is powered up. Next, press the Debug button. If everything compiles and programs properly, the DEBUG mode will appear with the first command line highlighted in green.

STEP INTO

I want to see the variable counter change, so I press the Auto Update button and also press the Show Variables button to open the variables display window. The variable counter should appear in the window. Next, I press the Step Into button to advance the program. If I keep stepping through the program, LED1 will turn on and then turn off several times.

After you've seen the LED flash on and off several times, look at the counter variable in the variable window and see if the value of the counter has changed to match the number of times the LED has flashed (it may be one higher, depending on where you stopped the program).

ANIMATE AND BREAKPOINT

Now, I set the cursor to the command line with NEXT in it and press the Toggle Breakpoint button. The NEXT command line should turn red, as seen in Figure 3. Once that is completed, I press the Animate button to make the program run. The program should step through the main loop and then stop at the NEXT command line. Click on Animate again, and the program will again stop at the breakpoint. Watch the variable counter change with each stop at the breakpoint.

RESET AND STEP OVER

If I click on Reset, the program will jump back to the beginning. Pressing Step Over will make the program jump past the FOR-NEXT loop and stop at the "High 2" command line. This is how you bypass a lengthy section of code to see other sections run.

ICD SUMMARY

It's hard to present an example like this in an article, but hopefully you understood what I was trying to demonstrate. The example above is quite simple, but hopefully you can see how handy the ICD can be for debugging your program. As your program grows, the complexity also increases. Trying to find out why a program runs, but isn't doing what you expect, is almost impossible without some help. The ICD is priceless for this, and yet it's included free with the BasicATOM software. Play with the debugger often to understand all its features. You can set multiple breakpoints or Run to Cursor multiple times, which is incredibly handy.

The ICD makes the BasicATOM chip/module one of the best beginner set ups on the market today. This also will teach you the basics of using an ICD. Microchip makes hardware debuggers that allow you to do all of the same functions in your PIC MCU circuit. Microchip's MPLAB ICD 2 — also known as the "hockey puck" — is one of the more popular ICDs offered by Microchip. It's the way you would debug an assembly code, C code, or a microEngineering Labs PICBasic coded program in the MPLAB IDE. (The MPLAB ICD 2 costs around $160.)

LISTING 1

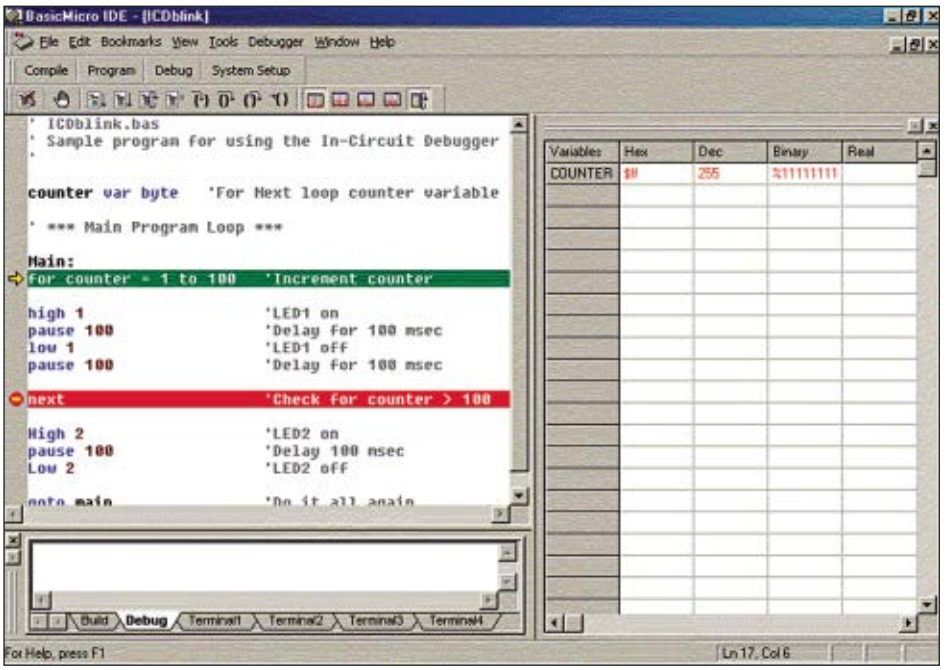
```
' ICDblink.bas
' Sample program for using the In-Circuit Debugger
'
counter var byte 'For Next loop counter variable

' *** Main Program Loop ***

Main:
For counter = 1 to 100   'Increment counter

High 1                   'LED1 on
Pause 100                'Delay for 100 msec
Low 1                    'LED1 off
Pause 100                'Delay for 100 msec

Next                     'Check for counter > 100

High 2                   'LED2 on
Pause 100                'Delay for 100 msec
Low 2                    'LED2 off

Goto main                'Do it all again
```

TERMINAL WINDOW

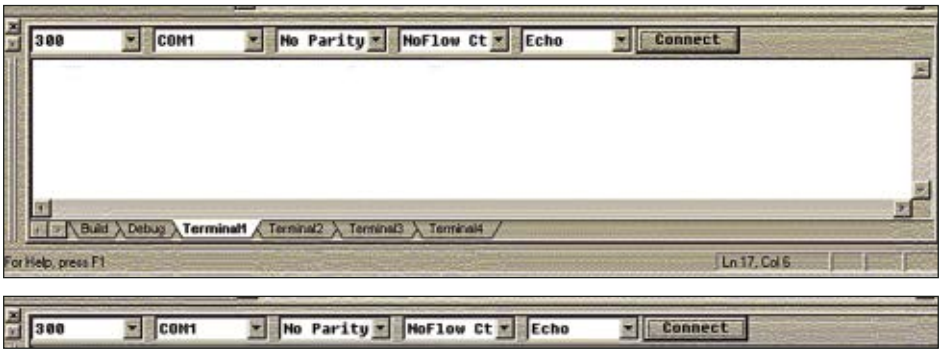
As I mentioned earlier, the BasicATOM has a DEBUG command. This method sends data serially to a built-in Debug window also included in the free BasicATOM IDE. The IDE has several terminal windows for serial communication. The graphic in Figure 4 shows BasicATOM debug and terminal windows. It has a selection bar to set up the window and allows you to connect to one of the various COM ports on your PC.

Any of the terminal windows can also be used as a debugger window, if you occasionally insert a SEROUT command that sends the status of a variable or pin. This gives you another method of debug, in addition to the ICD.

I use these windows often, but typically not for debugging since the ICD works so well. Additionally, I often use these windows for two-way communication between the Basic



■ FIGURE 3. A Toggle Breakpoint screenshot.



■ FIGURE 4. A BasicATOM terminal window.

■ FIGURE 5

ATOM and the PC. In fact, I demonstrate this in one of the projects in my BasicATOM book. In Chapter 13 of my book, *Programming the BasicATOM Microcontroller*, I use this window to communicate with the Ultimate OEM module and remotely control which I/O pin to drive high; thereby lighting one of eight connected LEDs.

TERMINAL SETUP

The terminal window can be set up in various formats. The most commonly modified option is the baud rate selection, shown in the first pull-down box. Here, you match this up to the baud rate that your SEROUT command uses (Figure 5).

Next, you can select the proper com port and then set up the other communication parameters, such as parity or no parity, flow control or no flow control. Also, you can set it to echo back and display what you type within the terminal window, after you hit the enter key.

The last item is the Connect/Disconnect button. When you are ready to receive or send data to a BasicATOM module, you would connect by clicking on the Connect button. You won't be able to program the BasicATOM if you use the programming port S_IN and S_OUT in your SEROUT command as the communication port, until you disconnect (these are the same connections used to program the BasicATOM). Using these pins, though, makes it easy to use since they are already connected to the RS-232 level shifter chip in the Ultimate OEM module and the PC.

You can also have more than one terminal window running by selecting them from the tabs at the bottom of the terminal window, as seen in Figure 6.

The terminal window is a handy tool, and having it as part of the BasicATOM IDE is very helpful. If you like to create projects that involve PC-to-microcontroller communication, you will use it often.

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CONCLUSION

I find that the BasicATOM ICD is just a great feature, no matter how you look at it. In fact, it's one of the features that helped sell me on the BasicATOM. If you are trying to teach someone programming, being able to step them through a program while the hardware changes for each command makes it much easier to understand.

The sample program I showed here flashed two LEDs on and off. Being able to watch the LED turn on and off after each HIGH or LOW command, respectively, is a great way to teach programming to the beginner.

When you get a program that acts strange — it looks like it should operate one way, but it does something different — being able to see the various variables and inner registers may tip you off as to why your code isn't working properly. I've spent many a night trying to debug code without a debugger tool. It's really a difficult task.

BIG NEWS

■ FIGURE 6

In addition to showing you the great debugger feature of the BasicATOM, I can finally officially announce something I commented about in a previous article. By the time this article hits the newsstand, you should see that new BasicATOM chips are available based on the new PIC16F886 and PIC16F887. These are the next-generation PIC MCUs that improve on the PIC16F876A and PIC16F877A, upon which the previous BasicATOMs were based. Basic Micro has also lowered the price significantly.

One of the complaints I had about the BasicATOM was the price of the BasicATOM chips. If you wanted to create a product based on the BasicATOM, spending $20 on a chip was too expensive. As I write this, the BasicATOM chips are scheduled to start selling for around $10 (with possible quantity discounts). This is outstanding news, because the BasicATOM gives you so many features — including floating point math and commands — which even PICBasic PRO doesn't offer. Check out these new BasicATOM prices, and if you are just getting started, give the BasicATOM chips another look. I honestly do not see a better deal out there for the beginner, or even the experienced user who needs a quick way to develop a product.

As always, contact me at chuck@elproducts.com with feedback on this column. I try to read them all and answer them as fast as I can. You'll also notice my website shifting from selling products to just supporting my books and articles. I just could not keep up with it all, so the selling part of my website is going to be shifting to other sources (so I can focus on writing more books and articles). Visit anytime you want at **elproducts.com**, as I hope to add more beginner tips to the website. **NV**

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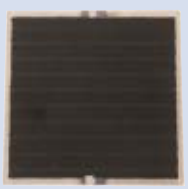

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■ BY LOUIS E. FRENZEL W5LEF

CELL PHONES — 10 Pounds of Technology in a 5 oz Package

NO OTHER ELECTRONIC PRODUCT INCORPORATES AS much of the latest technology as a cell phone, and especially in such a small package. When you stop and think about what is in a cell phone, it begins to dawn on you just how many varied electronics are jammed into your handset ...

Besides the RF section which is a sophisticated, two-way digital radio, the cell phone has at least one embedded controller that runs the keyboard and display, and does the other housekeeping. A second processor may be used if you have a multimedia or smart phone that downloads audio and video or uses a camera. These phones also come with their own operating system to manage email and other applications.

And don't forget the cell phone baseband functions that run the communications process including modulation, demodulation, coding and decoding, compression and decompression, A-to-D and D-to-A conversion, and related stuff.

Of course, there is the memory: a small amount of RAM and (today) larger and larger Flash memory. Oh yes, the LCD screen, color in most newer phones, and even the camera sensor and lens in camera phones. Then there are often separate receivers for FM radio or GPS navigation and the forthcoming TV receivers.

Finally, there is the power system with its lithium-ion battery, charger, and power management circuits. Name one other product that contains this full range of electronics. I haven't even mentioned the vast network of basestations and networking centers that have to be in place to let you make a call.

Most people consider their cell phone as their single most important personal accessory. It has to reliably handle the voice and messaging and other communications functions you have become addicted to, but it also has to make a fashion or life style statement for you, as well. Yet, as important as the handset is to us, we mostly take for granted what has to go on to let us make a call ... or do whatever. Few, if any, know the technology that makes it happen.

Here is an update for you electronic types who want to be more knowledgeable about what your cell phone does and how it does it. We'll also take a quickie look at where the cell phone is headed.

■ *Apple.* The phone with the most coverage and visibility is the Apple iPhone that went on sale in late June. At $499, it is expected to sell well just because it contains an iPod with 4GB or 8GB Flash song memory and a unique touch screen (no real keyboard). A 2.0 megapixel camera is built in, as is video capability. The iPhone uses quad band GSM/EDGE and includes a Wi-Fi 802.11b/g, as well as Bluetooth 2.0 radios.

THE RADIO TECHNOLOGY

The first generation of cell phones came out in the late 1980s as car phones rather than handhelds. They were nothing more than a trunk mounted, two-way FM radio. The first reasonably sized handhelds which we now refer to as "bricks," came on the scene in the early 1990s. Despite their size, they were really popular, even at the high prices. It wasn't until the mid-1990s that we got the first really small handsets, the Motorola StarTac being the classic example.

By the late 1990s, the cell phone carriers realized that they were fast running out of spectrum for new subscribers. Since they aren't making any new spectrum these days and the FCC (Federal Communications Commission) is auctioning off what precious little spectrum there is left for billions, you need deep pockets or some better technology to stay in business. So the mid-1990s saw the first of the second generation (2G) digital cell phones that used multiple access technologies to squeeze more voice calls into the same spectrum

■ *Helio.* The Helio Ocean is one of the newest phones on the scene. It slides open vertically for standard phone use and slides open horizontally for email with full QWERTY keyboard and landscape display. The radio technology is 3G EV-DO cdma2000 networks and features a 2.0 megapixel camera, 2.4 inch QVGA display, 200 MB memory, and full music (MP3, AAC, WMA) and video (MPEG-4, H.264) support. Features like email, GPS navigation, video-on-demand, and instant messaging are available.

previously occupied by a single analog voice signal.

The IS-154 standard used here in the US called time division multiple access (TDMA) put three voice signals into the previously single signal 30 kHz channel. The Europeans created their own flavor of TDMA called GSM (Global System for Mobile communications) that puts eight calls into a 270 kHz channel.

New digital voice compression algorithms allowed many more calls in a given bandwidth than analog methods permitted. It gave the carriers more subscribers and more income in the same spectrum. An added bonus was that digital communications techniques were much less influenced by noise and other radio interference problems. Voice quality improved as did reliability.

During this time, a new and different 2G radio technology was being developed and put forth by Qualcomm. Called code division multiple access (CDMA), it uses spread spectrum techniques to put even more subscribers in available spectrum. A new standard called IS-95 was developed and eventually adopted by some of the carriers. This version of CDMA allowed up to 64 voice calls in a 1.25 MHz band. Direct sequence spread spectrum (DSSS) with QPSK modulation was used. With different carriers using different radio technologies, obviously all cell phones were not interoperable or compatible. That's not a problem if you stay with the same carrier.

During this time, we also began to see some amazing semiconductor downsizing and repackaging of cell phone electronics by reducing chip sizes and putting more stuff into each chip. The system on a chip (SoC) came about. This allowed even smaller cell phones. Also during this time — with voice communications by cell phones truly established — carriers began to look for other ways to get more income out of their subscribers by offering data services like email, Internet access, and text messaging. A separate data technology was developed and promoted. For the TDMA GSM phones, general packet radio service (GPRS) was developed. It used one or more of the eight TDMA time slots to send data at rates up to about 40 kbps. The older IS-154 TDMA service was abandoned by most carriers in favor of GSM simply because it was less efficient and did not have a data capability.

The CDMA carriers worked and developed the A and B versions of IS-95 that included a slow (like 14.4 kbps) data capability. But development continued and the GSM carriers went further with an enhancement to GPRS called EDGE (enhanced data for global evolution). EDGE uses 8PSK modulation in the GPRS slots to boost data rates to over 100 kbps in some instances. The CDMA path was further improved by Qualcomm who introduced cdma2000 that included a data capability called 1xRTT that gave a packet data rate up to about 153 kbps. Both GSM/GPRS/EDGE and cdma2000 1xRTT are generally referred to as 2.5G or 2.75G technologies.

With all the technological development came some industry consolidation as companies bought, sold, and merged. Today, we have four major cell phone carriers in the US. These are Verizon and Sprint Nextel who run only cdma2000

SOME INTERESTING FACTS ABOUT CELL PHONES

• Most cell phones still operate in the UHF spectrum from 800 to 950 MHz. This spectrum is pretty much used up at this time. A new block of spectrum came along in the late 1990s and early 2000 time period called the Personal Communications System (PCS). It uses the spectrum in the 1,900 MHz range. 3G phones typically use spectrum around 2,100 MHz.

• Nearly one billion new phones were sold in 2006 (985 million). It is estimated that in 2007, the billion mark will be broken with some estimates as high as 1.2 billion.

• China is the largest cell phone user with about 400,000,000 subscribers. The US has about 200 million subscribers.

• The largest worldwide handset manufacturers in order of volume produced are Nokia, Motorola, Samsung, and Sony Ericsson.

• Several IC manufacturers have literally put all cell phone circuits on one chip, bringing the manufacturing cost of a low-end voice-only cellphone down into the $10-$20 range, creating the ultra low-cost handset (ULCH). It is expected to help increase subscribers in developing countries and countries with huge populations like China and India.

• An interesting development is the femto cell. A femto cell is a miniature basestation or cell site that can be packaged as a consumer product and sold to homes or small businesses without good cell coverage at home. Your cell phone will communicate with your own basestation which is connected back to your carrier via your high speed cable or DSL connection.

■ *Motorola*. One of the most popular cell phones in the history of the world was the Motorola RAZR with over 100 million sold. The new RAZR2 is similar, but slimmer than ever and has a larger, higher resolution screen. Its multimedia options include a 2.0 megapixel camera. The radio technology is either 3G WCDMA HSDPA, cdma2000 EV-DO, or GSM/EDGE.

networks; and AT&T (who recently bought Cingular) and T-Mobile who are the two big supporters of GSM/GPRS/EDGE networks. So, if you know your carrier, you now know what technology your cell phone uses.

THE PATH TO 3G

Cell phone development is an on-going, evolutionary process. Beginning in about 2000, plans for a third generation (3G) cell phone system were established by the International Telecommunications Union (ITU). ITU along with the third Generation Partnership Project (3GPP) created the wideband CDMA (WCDMA) standard that promised 384 kbps to 2 Mbps in 5 MHz wide channels. Also known as the Universal Mobile Telecommunications System (UMTS) or IMT2000, the WCDMA technology is the 3G upgrade path for carriers using GSM/EDGE. More recent developments are higher speed versions of WCDMA called High Speed Download Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) that gives data rates up to 7.2 Mbps. When combined, HSDPA and HSUPA are called HSPA for High Speed Packet Access.

Qualcomm came up with their own version of 3G with upgrades to their cdma2000 technology. They offer increasingly higher speed data rates in their 1.25 MHz channels, referred to as Rev A and Rev B. You will see the terms Evolution-Data Only (EV-DO) to refer to these higher data rate systems that can deliver up to 2.4 Mbps. China developed their own version of 3G called Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) which will be used exclusively in China.

The carriers have been rolling out 3G cell sites as their capital expenditure budgets permit. Yet few of us actually have 3G. If you do have it, you probably don't know it. If you have a cell phone with very high speed email or Internet access, then you probably have 3G. The newer PC cards that plug into a laptop slot for Internet access use 3G only. Otherwise, you are probably still with 2.5G. Seems like a lot of us still do not do fast email, downloads, or other things really requiring the extra speed. But that is changing.

1001 THINGS TO DO WITH A CELL PHONE

The cell phone has been called the Swiss Army knife of electronic devices. It does many things besides just making voice phone calls. We have text messaging, email, Internet access, music, games, videos, direction finding with GPS navigation, FM radio, and picture taking with built-in digital cameras. An all-purpose device, to be sure. But more is on the way as your cell phone carrier tries to figure out what services you will pay extra for each month. By far, text messaging and email are the biggest hits although music downloads to built-in MP3 players are growing in popularity. But as we get faster 3G phones and larger LCD screens, Internet access — which has not been all that popular — will come into its own. So-called dual mode phones now available have Wi-Fi or IEEE 802.11 wireless local area network (WLAN) radios built in so they can talk to any company access point or public hot spot like a laptop. With such a phone, you can make voice over Internet protocol (VoIP) voice calls via the hot spot if you do not have a good cell site connection.

Another hot application on the way is cell phone TV. Again, the small screen keeps us from latching on to the idea. Later this year and mostly next year, you will begin to see cell phone TV. Short video clips and specially formatted news, weather, sports, financial, and other content will be broadcast to cell phones. Qualcomm's MediaFLO technology has been adopted by AT&T and Verizon. It uses separate TV broadcasting stations that send the video to a separate TV receiver in the cell phone.

An alternate system used in Europe called Digital Video Broadcast-Handset (DVB-H) may be implemented by Modeo, a division of Crown Castle in the US. Although, no carrier has adopted it yet.

It is not likely that you will be able to buy a cell phone that will do all of these things but there will be enough models for you to select one that does the combination you want. For

■ *Research In Motion BlackBerry*. RIM's BlackBerrys have traditionally targeted the busy executive for business or government applications rather than the consumer. The new RIM Curve 8300 features the email system of RIM plus texting, a 2.0 megapixel camera with flash, full QWERTY keyboard, color LCD preloaded maps for GPS navigation, and expandable memory. The radio technology is quad band GSM/GPRS/EDGE.

example, if you want just music downloads, there are Samsung, LG, and other MP3 phones with huge hard drives or Flash memories to hold the songs. Apple's new iPhone combines an EDGE phone with an iPod. If you just favor email, you probably want a BlackBerry – the king of email phones. The Palm Treo phones also do email, as well as popular PDA functions. Phones from Verizon and Sprint Nextel have the best GPS navigation features and services now, but others are on the way. Nokia and LG have TV phones now, but others will be along soon.

4G PHONES IN THE WORKS

No kidding. Serious work is proceeding to create even faster, more capable 4G cell phones. The WCDMA/HSPA carriers are working with the ITU and 3GPP to create what is called Long Term Evolution (LTE). It uses orthogonal frequency division multiplexing access (OFDMA).

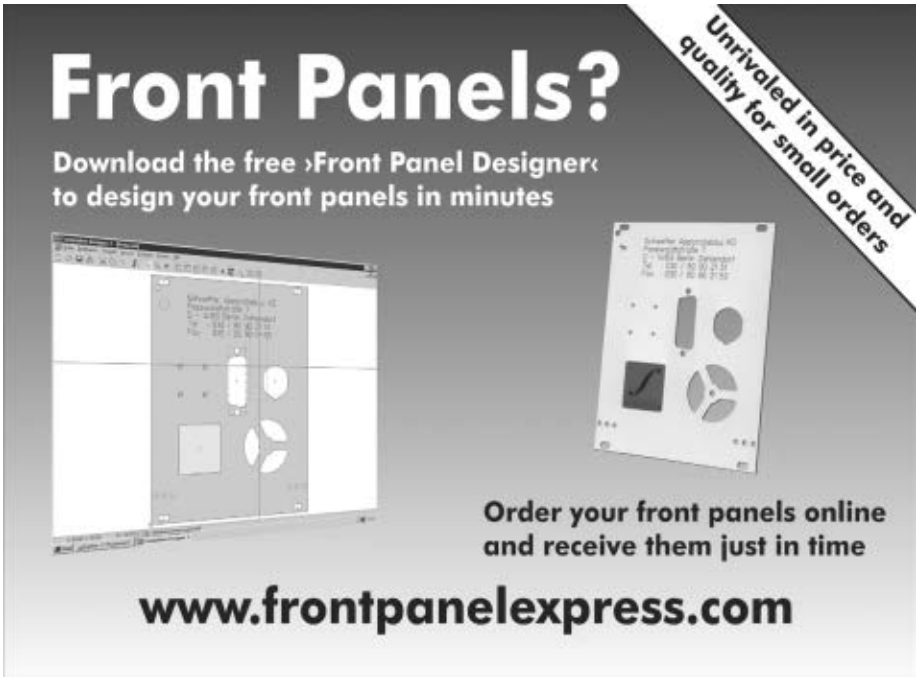
Recall that OFDM is the technique of transmitting high speed digital data by dividing the data into hundreds or even thousands of slower parallel paths and modulating each on separate adjacent but orthogonal carriers. OFDMA adds the technique of dividing the carriers and spectrum so that many users can share one wide band chunk of spectrum. LTE won't be available until about 2010.

The cdma2000 people will probably go with a 4G technology called Ultra Mobile Broadband (UMB). It was created by Qualcomm as an evolution to their cdma2000 Rev B system. It too uses OFDMA. With both LTE and UMB, promises of data rates to 100 Mbps to the handset have been made. No one is sure why we need this or what the end killer app will be, but we shall see beyond 2010.

The dark horse in the 4G race is called WiMAX. WiMAX (which is available right now) was developed as an alternative wireless competition to DSL and cable TV high speed broadband connections. It can also serve those small towns and rural areas where DSL and cable still don't exist.

New WiMAX basestations are being built now with services available in some areas currently, with much more on the way. The main carriers are Sprint Nextel and Clearwire. WiMAX also uses OFDMA. By using VoIP on WiMAX, subscribers can make phone calls, as well as do any other data-intensive applications like email, Internet access, or even video.

By putting WiMAX in a cell phone, you get a 4G capable phone. Most likely the LTE and UMB systems will become established as the primary 4G sources with WiMAX showing up mainly embedded into laptops as an alternative or complement to Wi-Fi. Something to look forward to around 2010. **NV**



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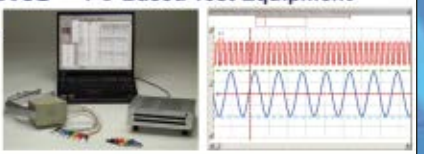

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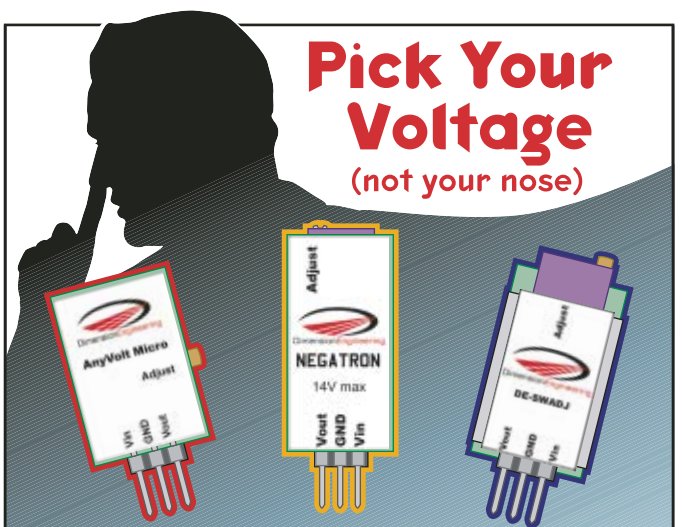

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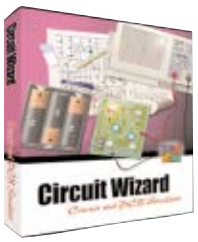

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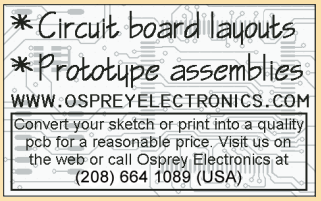

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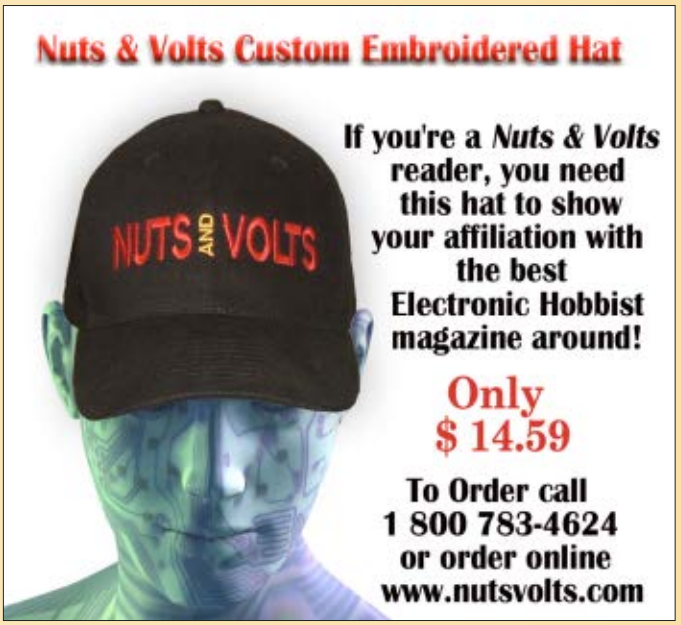

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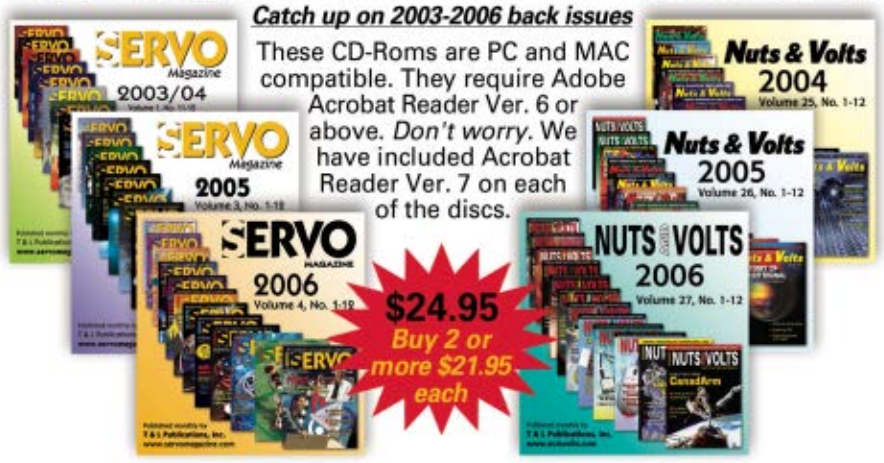

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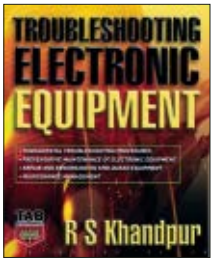

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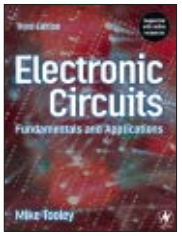

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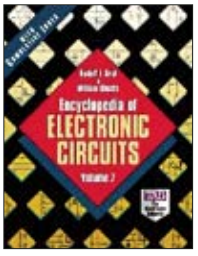

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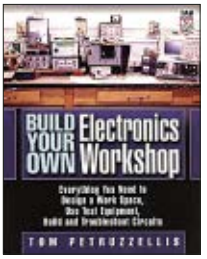

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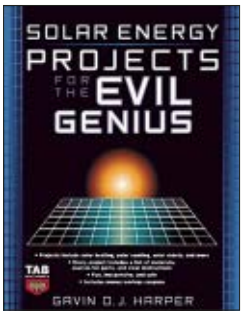
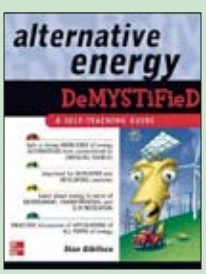


GREEN POWER ENERGY

Alternative Energy Demystified
by Stan Gibilisco
Publish Date: October 23, 2006



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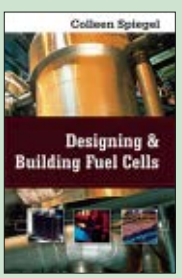
Designing & Building Fuel Cells
by Colleen Spiegel



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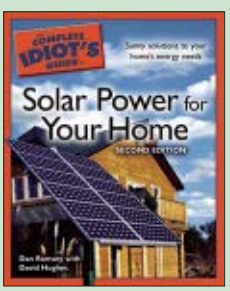
The Complete Idiot's Guide to Solar Power for Your Home
by Dan Ramsey / David Hughes
Publish Date: May 2007



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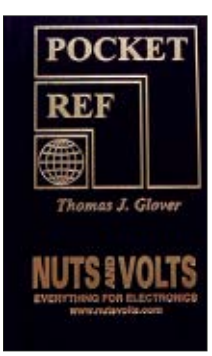
MUST HAVE

Pocket Ref
by Thomas J. Glover



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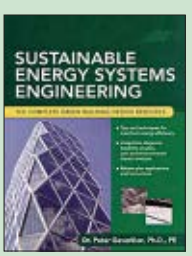
Sustainable Energy Systems Engineering
by Peter Gevorkian
Publish Date: October 10, 2006



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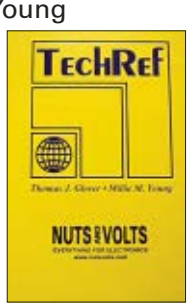
MORE INFO

Teck Ref
by Thomas J. Glover / Millie M. Young



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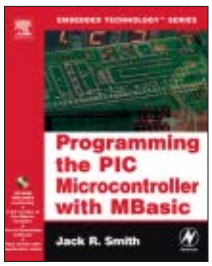
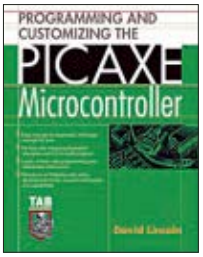
MICROCONTROLLERS

Programming the PIC Microcontroller with MBASIC
by Jack Smith



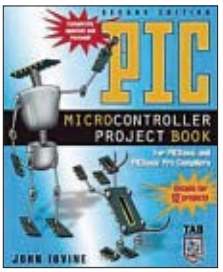
No microcontroller is of any use without software to make it perform useful functions. This comprehensive reference focuses on designing with Microchip's mid-range PIC line using MBASIC, a powerful but easy to learn programming language. It illustrates MBASIC's abilities through a series of design examples, beginning with simple PIC-based projects and proceeding through more advanced designs. **$59.95**

Programming and Customizing the PICAXE Microcontroller
by David Lincoln



Here's everything you need to harness the power of PICAXE, the inexpensive yet versatile chip that's taken the electronics community by storm. This beginner-friendly guide from IT pro and PICAXE expert David Lincoln shows you just what Revolution Education's PICAXE can do — and helps you make it do it! Packed with ready-to-build projects for all the flavors of PICAXE. **$39.95**

PIC Microcontroller Project Book
by John Iovine



The PIC microcontroller is enormously popular both in the US and abroad. The electronics hobbyist market has become more sophisticated. This new edition is fully updated and revised to include detailed directions on using both versions of the microcontroller, with no-nonsense recommendations on which is better served in different situations. **$29.95**

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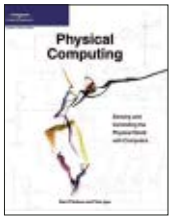

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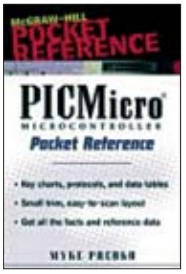
BACK ROOM

SPECIAL
PICmicro Microcontroller Pocket Reference
by Myke Predko



Designed to complement *Programming & Customizing the PICMICRO*, this book contains a minimum of verbiage and serves as an immediate device, code, and circuit lookup for experienced PICMICRO applications designers.

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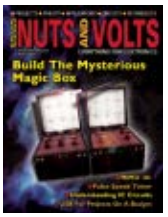
Magic Box Kit



As seen in our April issue.

We received such great reviews on this magic box kit that we decided to offer it in our store.

This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. Its delightful innovation will surely amuse you. More importantly though, it bewilders, baffles, and mystifies those observing this subtle magic trick.

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TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

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To be considered, all questions should relate to one or more of the following:

❶ Circuit Design
❷ Electronic Theory
❸ Problem Solving
❹ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
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ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.
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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

I was able to download the file from a RadioShack pro-97 police scanner. Using the Hyper Terminal program that comes with Windows XP, I saw a strange combination of card symbols, smiley faces, music symbols, and the alphabet. Can anyone shed some light on what language this is and what it all means?

#08071 **Bill Smith**
via email

I am wondering where I might find reprogrammable microcontrollers in common useage in everyday household life, that can be removed and reused if one does not have access to the parts store for a while.

#08072 **Gene Heard**
via email

How would I go about building a driveway sensor like the ones I've seen encased in PVC pipe, with a transmitter for remote operation? Also, maybe a project using some of the old C-Band actuators to power a gate.

Any ideas?

#08073 **M. Mars**
via email

I volunteer for a monkey sanctuary in Gainesville, FL, and we are looking for a monitoring system to make sure there is always heat available to all 85 of the former lab, Hollywood, or "pet" monkeys during the winter months. The main source of heat is about 70 ceramic chick heaters rated from 250 to 750 watts each.

Would it be possible to design a system that uses a thermal or current sensor at each heater that could be polled via the power line? If any station went out of limits for more than 30 minutes, it should produce an alarm at a central data acquisition microprocessor or computer. The 120V electricity to the heaters is delivered through a maze of circuit breaker boxes and GFCIs supplied from at least three power meters. A ground wire is provided on all wiring.

One of the design restrictions is to make it 100% reliable in reporting an outage or sensor failure. However, a small percentage of false alarms would be tolerable since the response would be for an intern to go out and connect a temporary heater. Finally, the system would need to be relatively inexpensive since the sanctuary is entirely supported by donations.

#08074 **Shannon Smith**
Lake Butler, FL

>>> ANSWERS

[#4074 - April 2007]

I've got an older computer (Plll at

500 MHz) and would like to add a larger hard drive (250 GB @ ATA133 or a 200 GB @ ATA100). I have been told by some that the computer won't be able to access the new drive's entire capacity and won't be supported by the micro-ATX motherboard (GT440ZX). Presently, its 'primary' hard drive is a 27.2 GB U-DMA ATA-66 which is now full (OS=WIN98SE). I would like to copy all the files on it and replace it with the larger drive.

If I install the 250 GB, will I be able to access the entire capacity and will it be supported by my existing motherboard or will I have problems?

Also, I need a recommendation for software which will allow me to copy ("mirror") and move all my files from one drive to the other.

Hard drive size accessibility is dependent primarily on the operating system (OS). You need to be running Windows 2000 SP4 or Windows XP with at least SP1 to access the full size of the hard drive. In some cases, you should also use the latest BIOS for the motherboard you have.

You need BIOS A04 to access the entire drive.

With BIOS A03, you are limited to a 32 GB drive size.

You can get BIOS version A04 from: **www.bcmcom.com/tech/GT440ZX/gt440zxbios.asp**

As to moving your OS and programs to a new hard drive, all the major drive makers have a utility program you can download for free to migrate over to the new drive.

Bruce Bubello
Wayne, NJ

[#4076 - April 2007]

Can anyone recommend a decent electronics glossary of terms or dictionary?

#1 I have a 1970 edition of *Modern Dictionary of Electronics* by Rudolf F. Graf, published by Howard W. Sams. It cost $7.95 when I bought it, but it is still in print at 10 times the price, and it is an excellent dictionary. I also have *Glossary of Communications* by Emerson G. Smith, published by Telephony Publishing, Inc. It has words that are not in the dictionary; it is probably out of print but you may find one on eBay.

Russell Kincaid
Milford, NH

#2 Why not use the 'Electronic Encyclopedia' option found on the **www.nutsvolts.com** website?

John F. Mastromoro
Saint Johnsville, NY

#3 Probably the best dictionary of electronics and communications terms is the *Wiley Electrical and Electronics Engineering Dictionary* that was last published in 2004. This dictionary contains in excess of 35,000 terms and will surely provide answers and definitions to more terms than we may think about.

The drawback is that this knowledge comes with a price and it can be

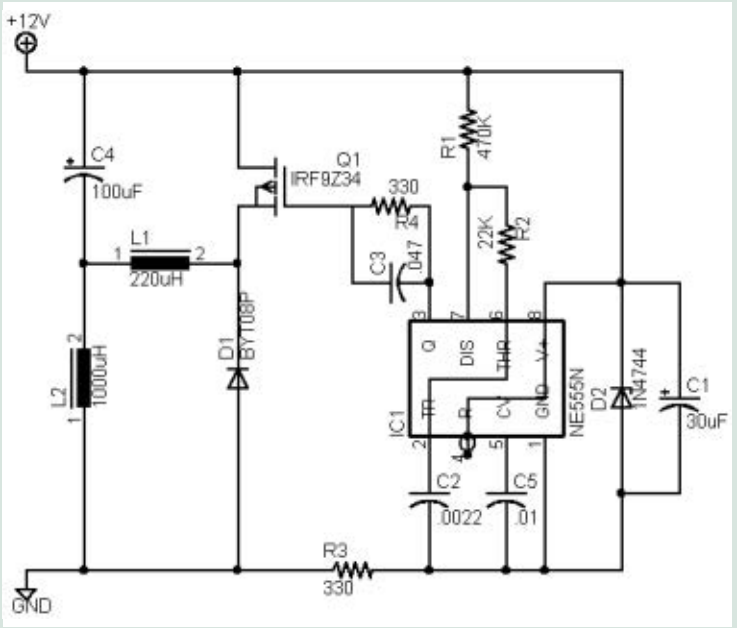
[#5074 - May 2007]

I have two lead-acid batteries, never used but two years old that won't take a charge. I'm sure that they became sulfated from sitting in a no charge condition. Is there a circuit I can construct to desulfate them?

#1 Check *Nuts & Volts* classified, p. 97, May 07, **www.wizbangplus.com**, it might work. Also, Google desulfators. If they are sealed type "gel cells," forget 'em.

Rod Hogg
Scott City, KS

#2 Alastair Couper designed a desulfator circuit which was presented in *Home Power* #77. That circuit appears here, with two additions: D2, a 15V 1W zener; and C5, a .01 µF cap. Some of the original parts specified have been changed to higher power units: the inductors are Mouser part #542-2316-V for L1 and 542-2324-V for L2; the fast recover diode, D1, is a BYT08P.



In use, the desulfator should be connected to the battery with short, #12 or larger leads. A transistor radio placed next to the circuit will pick up noise and let you know that it is pulsing.

Ed Schick
Harrison, NY

Battery Desulfator Errata

In my battery desulfator article on page 84 of *HP* #77, the value for C2 should have been 0.0022 µF, not 0.022 µF. My mistake.

I have put up a web page that will give more details to help you build and use the desulfator circuit. I will place updates there, and will add a guestbook soon to allow comments and questions to be posted. I encourage a group effort in this, since I don't have all the answers.

Alastair Couper
kalepa@shaka.com
http://shaka.com/~kalepa/desulf.htm

on the expensive side. It costs $84 purchased directly from Wiley and $76 purchased directly from Amazon, although you might be able to find a cheaper price from some of the used books sellers.

The ISBN for this dictionary is ISBN: 978-0-471-40224-4 With this information, you should be able to find it on Amazon or at other regular sellers of books.

Albert Lozano
Edwardsville, PA

[#6071 - June 2007]

What technology is used in the customer sensors above the grocery store doors to detect an approaching customer? Are these units available new or surplus anywhere?

Most all grocery door sensors are PIR technology (Passive InfraRed), some are ultrasound. PIR is used in automatic flood lights, etc. You can easily modify one for a door sensor or whatever. About all hardware chains have them.

Rod Hogg
Scott City, KS

[#6072 - June 2007]

I need to interface a GPS engine serial data out to two different devices. I would also like to isolate the three units from each other. Can the serial data output from a GPS engine drive two opto-isolators directly, and if so, would the output of the GPS be connected directly to the isolator input? Next, are there opto-isolators that have one input and two or more outputs?

Avago (was HP) and others make the 6N139 optocoupler, which requires only 0.5 mA to operate and has a 400% current transfer ratio, which means it will actually amplify the signal to about 2 mA. Connect the two optocoupler LEDs in parallel to

[#6075 - June 2007]

I need a simple circuit that would supply a two second on pulse and be off for 10 to 12 minutes. It should repeat this cycle over and over again. The on pulse would drive a 3 VDC relay. This would be powered from a 5 VDC power supply. Any ideas?

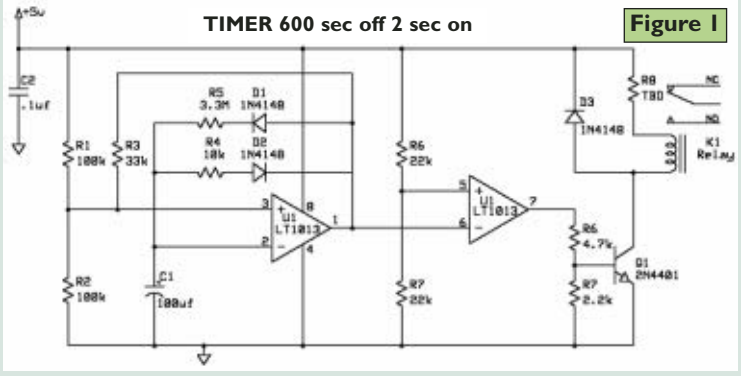
#1 This circuit (Figure 1) is an update of a National Semiconductor circuit for the LM324 with a better op-amp and a close relative of the 555 timer IC. The divider R1/R2 provides the switching thresholds with some feedback through R3. C1 needs to be a low leakage type with good tolerances and get charged through R5 and D1. R5 and C1 determine the off time. You can change the time by increasing/decreasing R5. Discharge happens through R4 and D2, and is responsible for the on time; R4 can be changed if other times are required. The second half of U1 increases the switching speed and ensures crisp transitions. R8 is a resistor to adapt your three-volt relay coil to the five-volt supply, which should be stabilized. Quartz timing should not be expected from this circuit.

Another approach would be a small microcontroller such as the PIC12F675 with a small Basic program doing the timing. You can then use different oscillators to improve the accuracy of the times (RC/ceramic/crystal).

Walter Heissenberger
Hancock, NH

TIMER 600 sec off 2 sec on

Figure 1



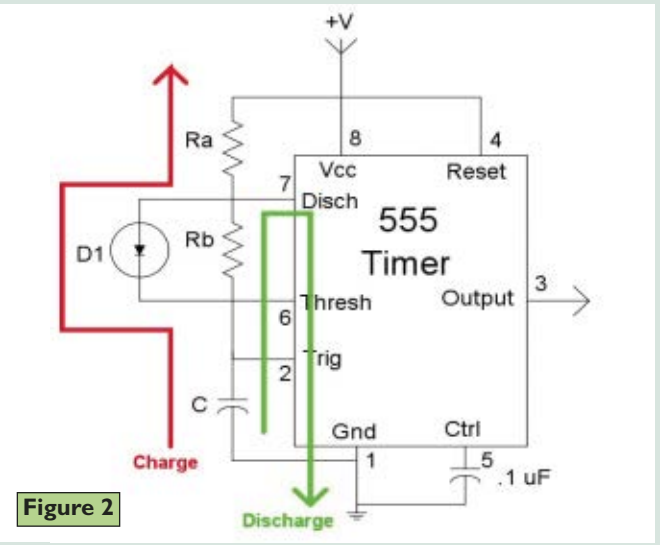


Figure 2

#2 The very simple answer to this problem is the venerable 555 timer in a confirguration I call the "universal timer circuit." In Figure 2, the charge path is ONLY through C and Ra, while the discharge path is ONLY through C and Rb; this effectively gives independent charge and discharge times. The timer output is low as long as C is charged and goes high when the voltage across C goes below 1/3 Vcc. The charge time T1 is given by: T1 = .693 x Ra x C, while the discharge time is given by: T2 = .693 x Rb x C.

In your application, you need a very long discharge time (600 seconds or 10 minutes), and a much shorter charge time (2-3 seconds). Using a C of 100 µF and the above equations, an Ra of 33K will give a high on the output for approximately 2.3 seconds, and an Rb of 10 meg will give a low on the output for approximately 693 seconds or 11-1/2 minutes. Of course, it would be a good idea to use a high quality, low loss electrolytic capacitor for C. The circuit works fine with a +5 volt supply.

Charles Irwin
Hendersonville, NC

the TTL output of the GPS module, each with their own dropping resistor (use 2.7K ohm for the 3.3V supply and 5.8K ohm for 5V) to the positive supply. This will ensure that each optocoupler will get the same current. Use a 3.3K on the other side to get a TTL signal for a 5V supply (2.2K for 3.3V). You can use this TTL directly or drive a TTL to RS-232 converter such as the DS14C232 or MAX232 if you need an RS-232 signal, which is most likely.

The GPS module will have to sink a little more than 1 mA — which should be easy, but needs to be checked.

The input side can be done with another 6N139 optocoupler, but only one can talk at a time to the GPS unit. You can use a master/slave arrangement or a time division arrangement, depending upon your requirements.

You can find the input circuit in Avago's *Optocoupler Designer's Guide* at **www.avagotech.com/**. There is also Application Note 951-1, for low current optocouplers. Sharp has also good information about optocouplers.

Walter Heissenberger
Hancock, NH

[#6073 - June 2007]

I would like to do some kernel debugging and the software I am using requires the use of one PC to monitor another PC. In the past, this would be done using a null modem cable between the two serial ports. Now with only USB ports, I am wondering how to create a null modem cable.

One thought would be to get two USB-to-serial port adapters and hook a null modem cable between them. I'm not sure that would work, and even if it did, a more direct approach and explanation would be much appreciated.

The USB-to-serial converter approach is a viable one and actually has some benefits, since you will get 500 kbd to 1 Mbd out of them. However, on some of them, the status lines are not, or not all of them are implemented. If you need only RX and TX, then the converter route is an easy way to solve the issue. I have used them with Bray's Terminal program extensively with good success (**http://bray.velenje.cx/avr/terminal**).

Microchip has a low cost USB serial analyzer using the Microsoft .NET environment and it is open and well documented. It was primarily intended for USB to I^2C/SPI/USART but they also had the foresight to provide the DLL and document it very well. You can use up to four of them in one PC and it allows you to use scripting, templates, and reprogramming. I did notice that the timing seems to be far better with this approach, but only RX and TX is available with a TTL swing, although you'll have far more control over it.

Walter Heissenberger
Hancock, NH

[#6077 - June 2007]

How hard would it be to make my APC UPS more usable during extended power outages by using 12 volt Optima batteries? Would the charge controller be overtasked? Or, would it be better to just buy a much bigger unit? I want scalability dependent on me, not what the company offers.

#1 Generally speaking, a UPS is designed to provide power to a computer long enough for the computer to be safely shut down. UPSs are not intended to be battery backup power sources for the duration of a power outage. Otherwise, the UPS would be designed for easy connection to external batteries.

It is probably not practical to modify your UPS to work with external batteries and you may create a fire hazard and invalidate your fire insurance.

There are commercially available inverter/chargers, that in conjunction with external batteries, will function as a battery backup power source as you desire. Search eBay for "inverter charger." Many inverter/chargers include a automatic transfer switch that will automatically switch the computer from the normal AC power to the inverter during a power outage. However, the transfer switch may not be quick enough to keep your computer running during power transfers and you would need to insert the UPS between the inverter/charger to keep your computer running at the start of a power outage.

Optima batteries are fine just make sure to use the yellow top (deep cycle) variety. Pairs of golf cart (6 VDC) batteries (2GC) are probably more economical to use for backup batteries but you will need to vent these outside any building if they are not a sealed type (Gel or AGM).

Robert Wheeldon
Jefferson County, WA

#2 You can add an external battery for longer run time, but it's not a good idea. I have taken apart many APC UPSs, as well as other brands. Generally, the charge controller is nothing more than a three-pin regulator (such as an LM317) and will have no problem charging the larger battery as it is current-limited to one amp or less. It will simply take longer to charge. The problem is that the inverter transistors are not well heatsunk.

The heatsinks used are small and with poor or no airflow. In one unit, the heatsink was nothing more than a big chunk of aluminum with no fins at all! It was simply a thermal mass. These heatsinks are acceptable for the short run time of the factory-installed battery, but will result in overheating and potentially a fire hazard if a larger battery with a longer runtime is used.

Additionally, I've found that the inverter transformers themselves have similar thermal problems. If you run them for longer than the short runtime they were designed for, they get very hot and are a fire hazard, as well.

Buy yourself a larger unit that will safely get you the runtime you require.

Ben Hall
Harvest, AL

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IN THE SPOTLIGHT

An Interview with Paul True

President, Linx Technology

by Marvin Mallon

The spotlight this month is on Linx Technology whose corporate headquarters is located in Merlin, OR, a small community northwest of Grants Pass. The privately owned company moved into this purpose-built facility in late 2006. The 20,000 square foot building houses many amenities for the two dozen employees including a game room, '50s theme lunchroom, four hole putting green, and more.

Paul True, whose long history of business creation started at age 18 on his mother's dining room table, founded Linx in 1997. His parents didn't allow a TV in the house until he was 15, so his early years were filled with *Popular Science*, *Popular Mechanics*, the *Book of Knowledge*, electronic kits, small explosions, and numerous fires. Soon after, he started his first company, Mytec, an electronic service center. Professional Video Warehouse, a nationwide distributor of video equipment, followed this. He then founded NRG Research, a manufacturer of lighting and power products for the video industry that continues in business today. In response to the lack of reliable and easily applied wireless solutions, Paul dedicated his energy and personal resources to create Linx and fulfill a vision for providing cost-effective RF solutions that could be easily applied by engineers of all skill levels.

Marvin: What purpose did you have in mind when you founded Linx Technologies?

Paul: Linx Technologies was created with the belief that every engineer should have the option of using RF technology. Radio frequency is a complex science, requiring a unique grasp of advanced technical issues and complex legal requirements. Adding wireless capabilities to a product has traditionally been a costly and time-consuming proposition. Engineers without deep expertise in RF may find themselves ill-equipped to analyze competing technologies or implement chosen solutions. As a result, many companies and engineers have been unable to benefit from the addition of RF technologies to their products.

M: How do your products differ from what is presently offered to the engineering community?

P: The overall market for RF solutions is highly competitive, filled with companies focusing on emerging standards, cutting-edge technologies, and the pursuit of ever-higher frequencies and data rates. Instead of complexity, Linx has taken a path of simplicity intended to allow engineers of all skill levels to quickly and cost-effectively achieve wireless success. Linx products are designed for ease of implementation, reliable performance, low-cost and a high degree of application flexibility. Most importantly, any engineer — even those without RF experience — can quickly and cost-effectively achieve wireless success.

M: Are there any newly developed products ready for release?

P: Right now, we have some of the most exciting products in our history entering the market and some fantastic innovations in R&D, as well. These include:

• *High Security Solutions for Control and Command Applications.* There is a lot of excitement centered on the recent release of our CipherLinx™ encrypted remote control technology. CipherLinx security is based on a core algorithm developed by the NSA and considered one of the most secure encryption algorithms available.

• *RF Transceivers.* The company will shortly introduce the LT series; a family of low-cost transceiver modules it anticipates will be uniquely positioned and highly successful.

• *Expansion of OEM Product Line.* Linx will continue to expand its OEM product family with a solid-state relay function module, and specialized consumer and industrial remotes.

There is one more that is unlike anything we have ever offered in the past that I am personally very excited about, but it's a bit too early. Let's just say innovation continues to flourish here at Linx and stay tuned.

M: Finally, please summarize the extent of your present product line.

P: We manufacture and market a diverse array of modules covering both analog and digital applications. Our RF modules offer long range, low power, stable performance, and ease of use. Additionally, no external RF components — other than an antenna — are required for operation. Our products follow as closely as possible to a wire-line model. This transparency simplifies design and allows a high degree of protocol flexibility.

We offer personalized support, superior evaluation platforms, inspection and pre-screening services, and informative application notes. Interested individuals can learn more about all of our products and services by visiting our website at **www.linxtechnologies.com**. **NV**

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Details at Web Site

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